Cryo-mechanical solutions for a cryostat equipped with large window:

The PHAROS case

- INTRODUCTION
- HEAT LOADS
- WINDOW
- ANTENNA LOGISTICS
- CONCLUSIONS

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Where is PHAROS from?

- Focal-plane Array for Radio Astronomy, Desig, Acces and Yeld. FARADAY (EC FP5, K-band, 7 beams)
- Phased Array for Reflector Observing Systems. PHAROS (EC FP6, C-band, 4 e-beams)

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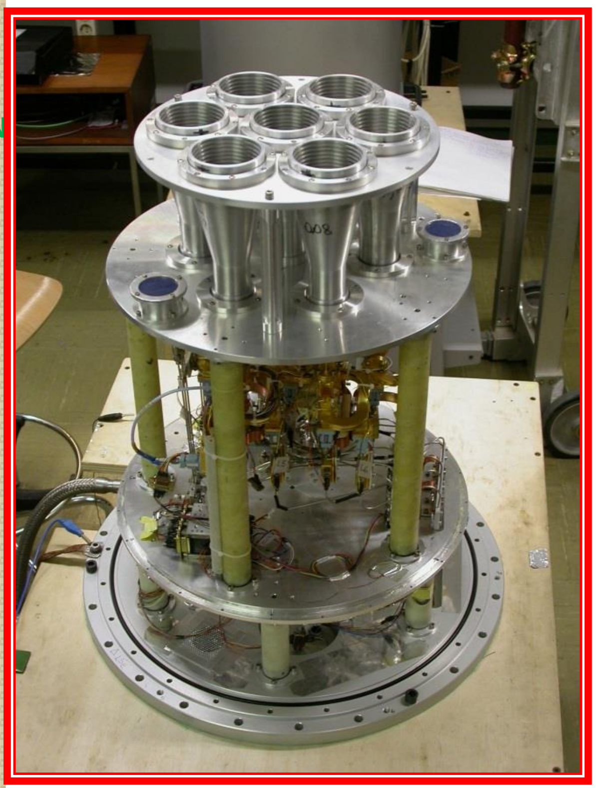
Actors: RadioNet

MMIC	Cryostat	Array	Signal path	Software	System design
Mecsa	INAF	The University of Manchester Jodrell Bank Observatory; THE UNIVERSITY OF BIRMINGHAM	CSIRO		ASTRON

The challange: Large windows



7 horns , K Band	
Volume	**110 Liters**
External Suface	**1,30 m^2**
Shield Surface	**0,98 m^2**
Window Surface	**500 cm^2**

The challange: Large windows

Pharos	
Volume	**110 Liters**
External Suface	**1,30 m^2**
Shield Surface	**0,90 m^2**
Window Surface	**2100 cm^2**

HEAT LOADS – 2° stage

- through coax cables
- through DC wires
- LNA
- through window

- Coax UT85 SS:
  8.4 mW /meter (20K…300K)
  1.0 mW /meter (20K…70K)

UT85SS 20K…70 K Heat for 1 mt	
NOW	13 mW
COMPLETE	220 mW

- AWG34 Phosphor bronze: 5 mW / meter
  i.e. 20 x AWG34, 1 mt long, carry 100 mW

- Traditional LNA (Te=2K, G=40dB, Po_1=+5dBm): 40 mW
  LNF LNA (Te=2K, G=40dB, Po_1=-10dBm): 4 mW
  i.e. 110 x LNF LNA: 440 mW

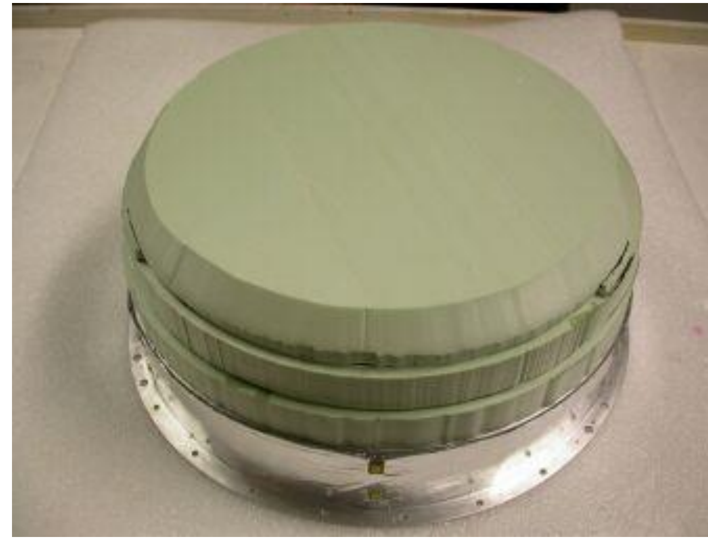
HEAT FLOW THROUGH WINDOW

- Due to black body radiation law, if black surfaces, 300K-20K: 45 W
- But Vivaldi array is shiny metal, realistically, ≈ 5…10 W. Anyway IR filter is required .

- Candidate materials has been tested extensively by experimental research. It required months.
- An ad hoc cryo test bench has been built.
  It was a "composite bolometer" cooled by CTI350.
  Accurate thermometers has been used to measure both temperatures.
  Resistors and black smoked surfeces has been used to calibrate the bolometer

HEAT FLOW THROUGH WINDOW

No.	Materiali 80 K	Materiali 20 K	ΔT (K)	P (mW)	$\eta = P/P_0$ (%)
		Bolometro A			
1[1]	-	-	10.4	237.6	100.
2[2]	-	-	5.80	129.7	54.6
3	PP2	-	4.30	94.58	39.8
4	BP	-	5.00	110.9	46.7
5	BP + PP2	-	4.00	87.54	36.8
6	PP2 + BP	-	4.00	87.54	36.8
7	STY	-	3.20	68.79	28.9
8	HF71	-	4.20	92.23	38.8
9	"	PP4	2.70	57.06	24.0
10	STY	"	1.28	23.76	10.0
11	HF71+51+31	"	1.17	21.19	8.9
12	4x PP2	"	1.04	18.14	7.6
		Bolometro B			
14	STY+BP1	PP4+BP1	2.00	10.56	4.4
15	COMP+BP1	"	2.54	13.67	5.7
16	STY+BCB	"	1.22	6.08	2.5
17	"	PP4	3.47	19.02	8.0
18	STY	PP4+BCB	1.34	6.77	2.8
19	2xPP2+BP1+2xPP2	PP4	2.28	12.17	5.1
20	BCB	-	12.3	69.78	29.
21	2x(PP4+BP1)	PP4+BP1	2.50	13.44	5.6
22	2x(PP2+BP1)+PP2	PP4	2.00	10.56	4.4
23	"	PP4+BP1	1.35	6.83	2.8
24	KLE 130	PP4	5.90	32.99	13.8



without IR Filter : 5…10 W
with IR Filter : 0.14…0.28W

Wafers of foam PP2 and a black thin polietilene sheet was applied to second stage (20K) and first stage (70K).

Heat flow has been reduced to the 2.8% of the non filtered situation, so the estimate residual flux is ≈0.14…0.28W, say less than 0.3W.

The WINDOW

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Requirements:

- Resist to the weigh of air pressure, 2000 Kg
- Transparent to RF

Preceding experience (Faraday) : thin film surrounded by thick foam.
Air weigh ≈500 Kg.   Rreinforcing ribs needed.
But PHAROS requires no ribs nor spokes.
Another solution needed.

Half sphere appeared the most functional and elegant solution because:

- Strongest shape to air pressure
- Invariant thickness vs any EM radiation direction
- Do not shadow the pattern of wide angle feed.

The WINDOW

- Which material?

The ideal window is made by a low reflection material ($\varepsilon_r \approx 1.0xx$ and thickness<<λ), low loss material (tan δ <1E-3), strong enough to carry 2000Kg, moldable as half sphere.

This material has been looked for but not found.

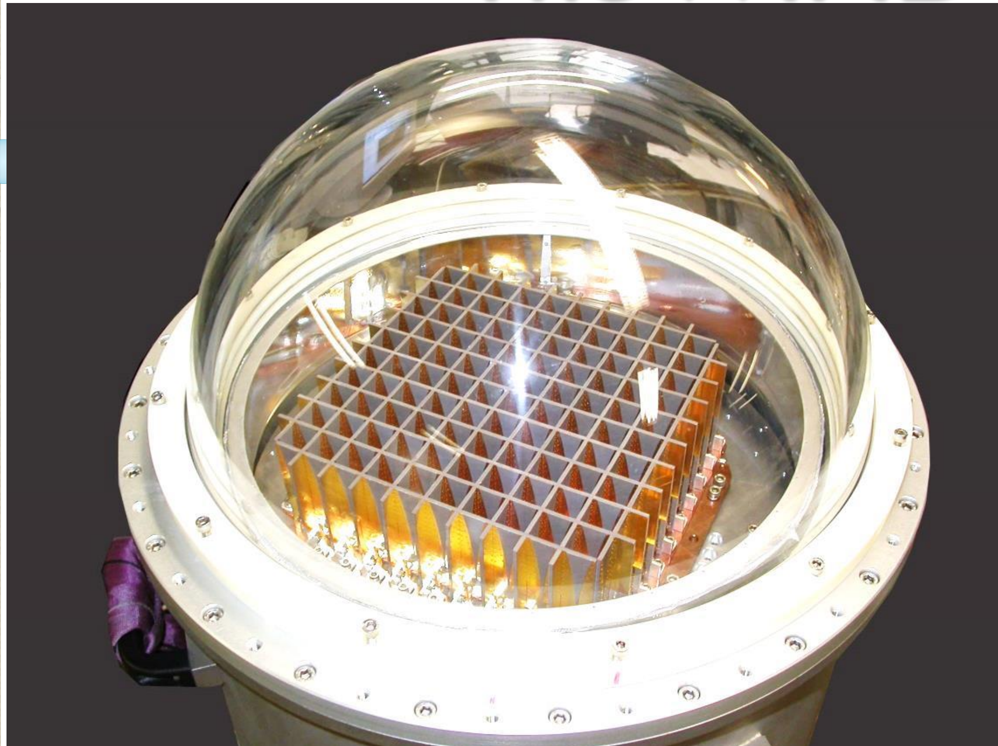
Some plastic has been considered: Plexiglass (chem: PMMA) and Policarbonate (chem: PC), both moldable.
The Plexiglass shown apparently more robust, easier to mold, easier to find on the market and lower tan δ .
Given the big air pressure weight, the minimum thickness has been evaluated.

The thickness has been chosen in order to satisfy 2 criteria:

- thickness greater than the safety minimum
- thickness = $\lambda/2$ at center frequency in order to minimize reflections.

The resulting thickness is 16 mm.

The WINDOW



INSIDE THE CRYOSTAT

- Six G-10 barrel support the cold plates.
  Activate charcoal trap
  May type of different thermal contacts has been tryed

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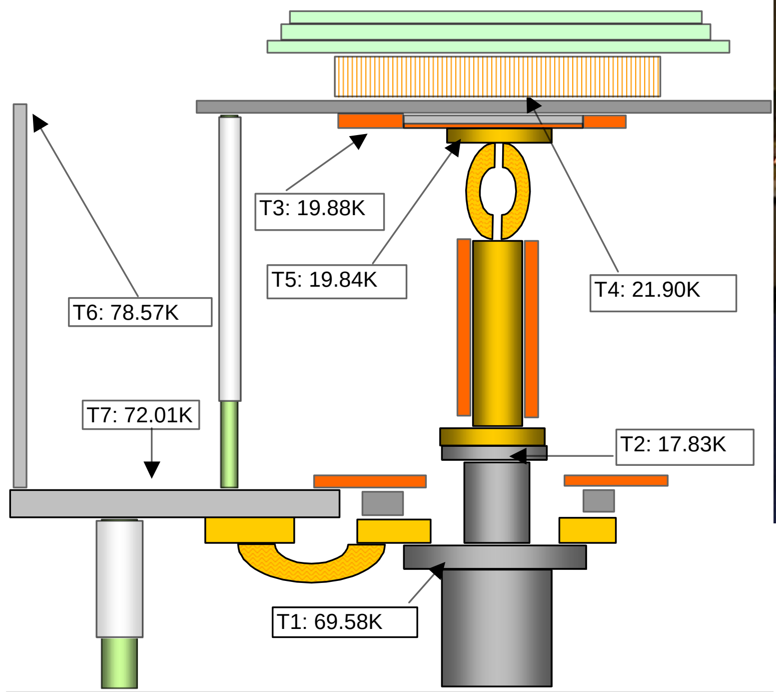
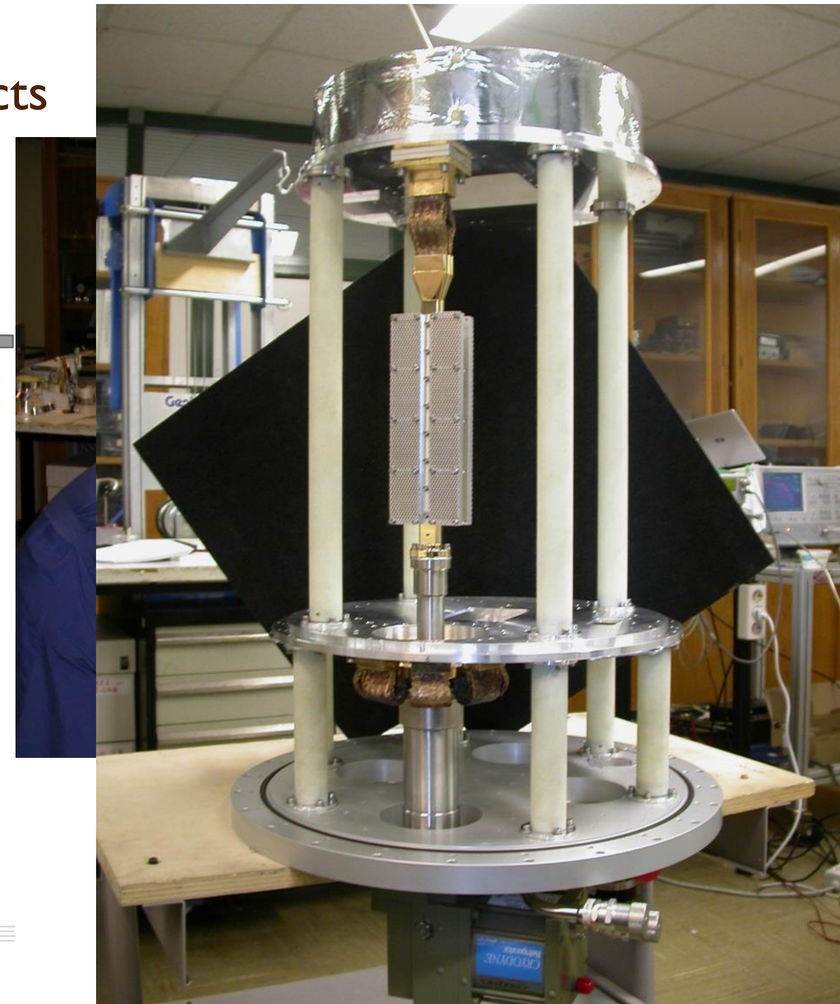
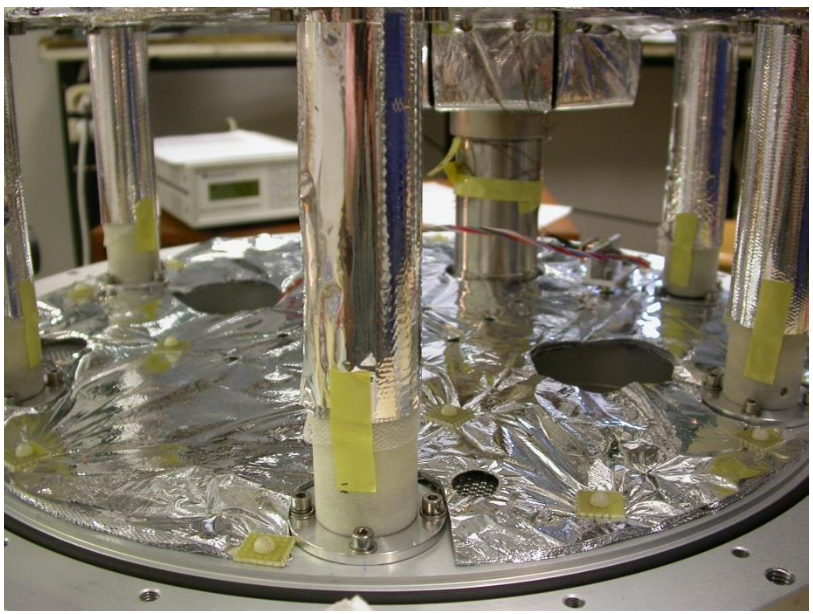




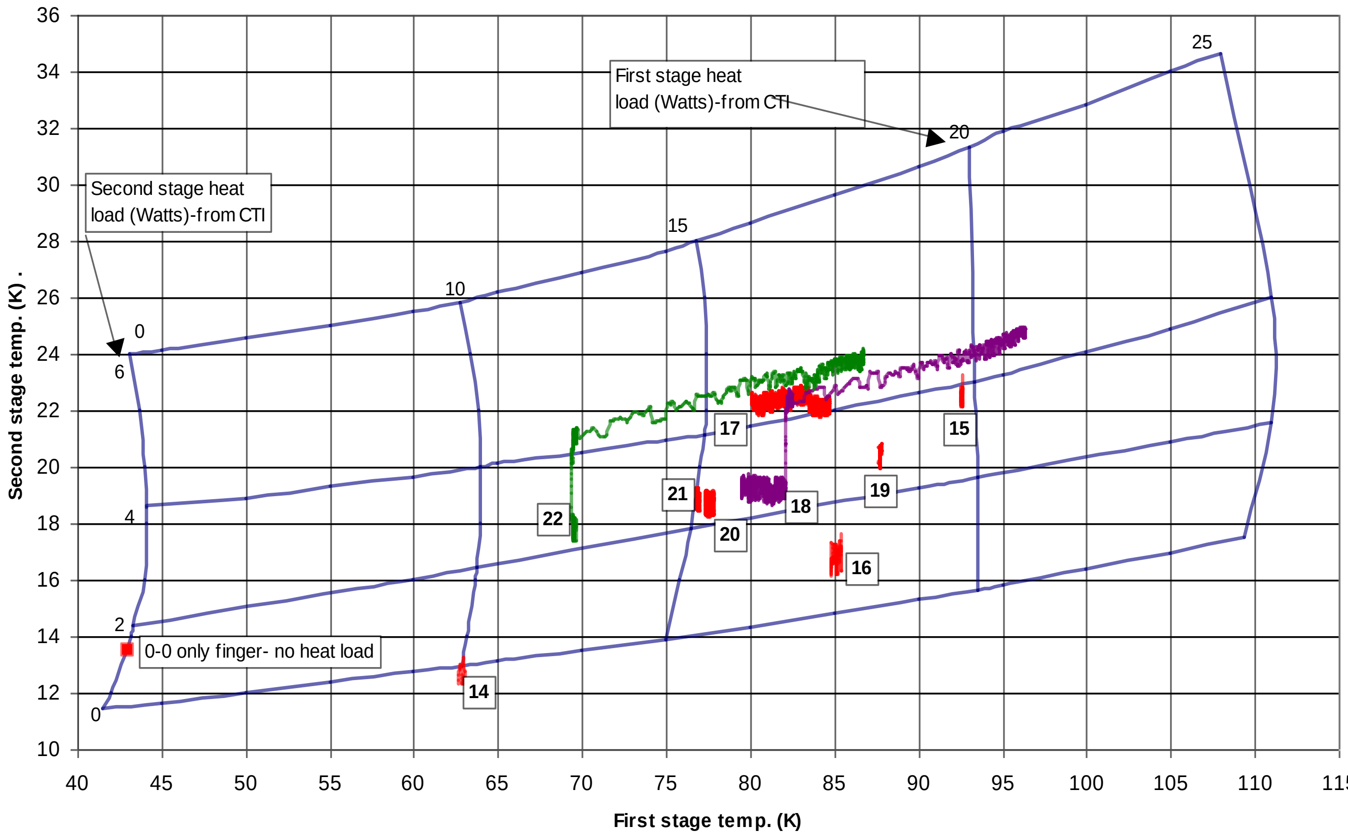
SUPER-INSULATION

Melius abundare quam deficere

(the more is better)



HEAT LOAD VERIFICATION



Actual temperatures are overlapped on the standard cryo-capability graphic

The SIZE of CRYOCOOLER

BRANDS	
Formerly **CTI- Cryogenics** most sold	**Sumitomo** best selling

COMPRESSORS	
6 KW (40 SCFM)	**2 KW** (14 SCFM)
May drive: One 12 W cryocooler Three 4 W cryocooler **Δpressure: 170 psi**	*May drive:* One 4 W cryocooler **Δpressure: 125 psi**

Higher is the Δpressure, Higher is the cooling capability .

But the Δpressure is reduced by pressure drop along pipelines.

The ROLE of the ANTENNA

- Does the choose of cryocooler size is a matter related to the PAF receiver only?
- Or conversely is it a trade off between receiver design and logistic antenna capability?

- We think the latter.

- In SRT, 100 mt long pipelines has been designed in order to get a negligible pressure drop even with He flow as high as 40 SCFM (6KW sized compressor).
- The use of 12W cryocooler is allowed, but it would waste the whole available He flux. For this reason a 4W cryocooler has been used even if it is little overloaded.

CONCLUSIONS

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- The PHAROS cryostat has been build and it's operative since Y 2008. Now at JBO.
- The most cryogenic challenging difficulty was the window as large as 37 cm.
- The dome is plexiglass made, 16 mm thick, vacuum resistant, RF transparent half sphere.
- Heat flowing along RF path has been minimized by use of a wafer of foam sheets
- Heat flowing through metal shields has been minimized by extensive use of superinsulation blankets.

CONCLUSIONS