The Greenland Telescope

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on behalf of
The GLT Project

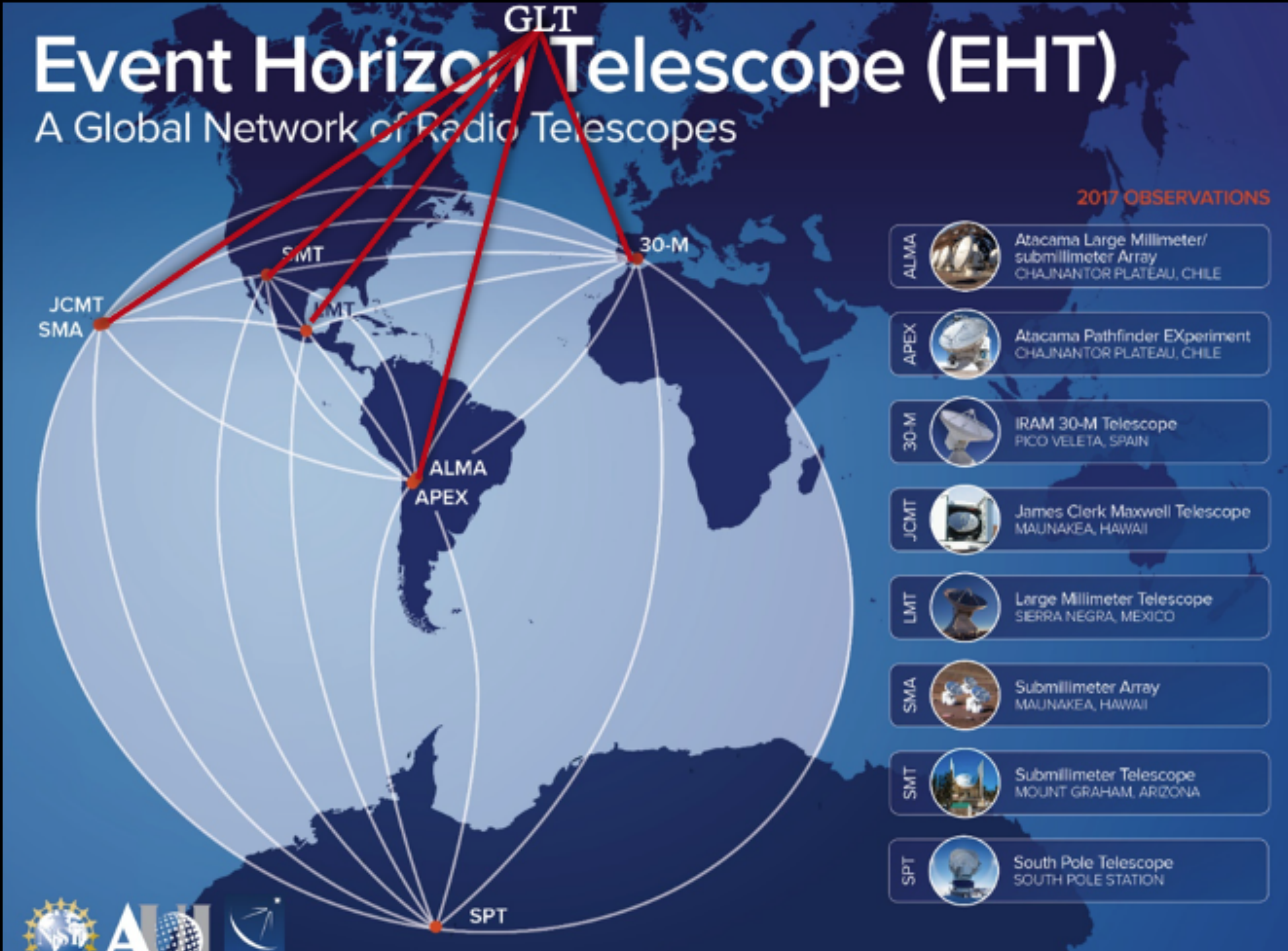
Academia Sinica Institute for
Astronomy & Astrophysics

CENTER FOR ASTROPHYSICS
HARVARD & SMITHSONIAN

Aarhus University, Niels Bohr Institute,
Technical University of Denmark,
the University of Southern Denmark

Current Status

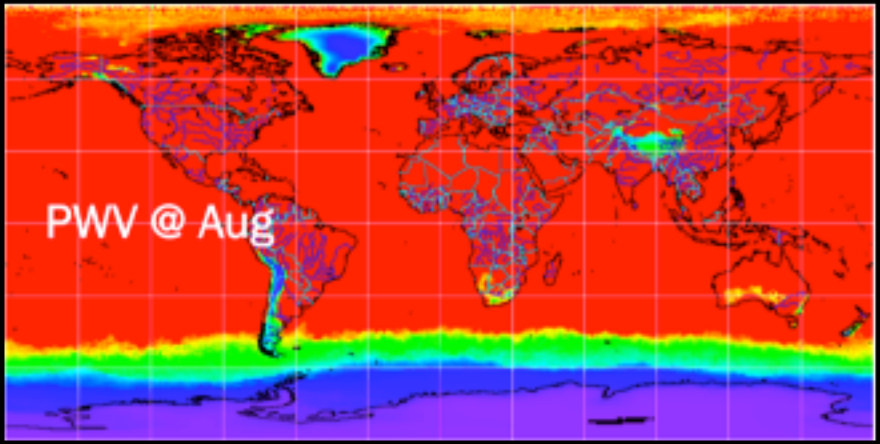
- The Greenland Telescope has been operating in Pituffik (Thule), Greenland!
- First light at the end of 2017!
- VLBI observations (86, 230, 345 GHz) since April 2018 !
- Joined Event Horizon Telescope and Global Mm-wave VLBI Array
- Developed remote/local operations
- 345 GHz fringes detected between GLT and ALMA
- In preparation for moving to Greenland summit.

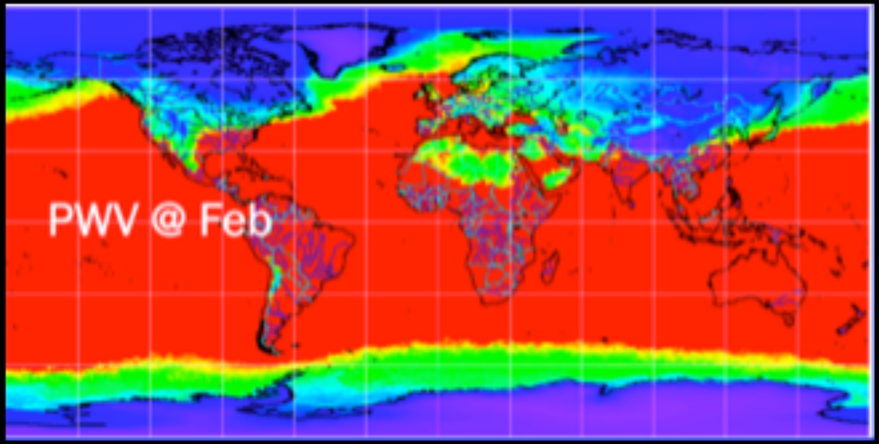


Event Horizon Telescope (EHT)
A Global Network of Radio Telescopes
GLT
SMT
30-M
JCMT
SMA
LMT
ALMA
APEX
SPT
2017 OBSERVATIONS
ALMA
Atacama Large Millimeter/ submillimeter Array
CHAJNANTOR PLATEAU, CHILE
APEX
Atacama Pathfinder EXperiment
CHAJNANTOR PLATEAU, CHILE
30-M
IRAM 30-M Telescope
PICO VELETA, SPAIN
JCMT
James Clerk Maxwell Telescope
MAUNAKEA, HAWAII
LMT
Large Millimeter Telescope
SIERRA NEGRA, MEXICO
SMA
Submillimeter Array
MAUNAKEA, HAWAII
SMT
Submillimeter Telescope
MOUNT GRAHAM, ARIZONA
SPT
South Pole Telescope
SOUTH POLE STATION
NRAO

Greenland Summit

- Criteria for new submm site for VLBI
  - High and dry submm sites
  - Mutual visibility with SMA and ALMA
  - Logistics and accessibility
  - Unique VLBI baseline





Greenland Summit

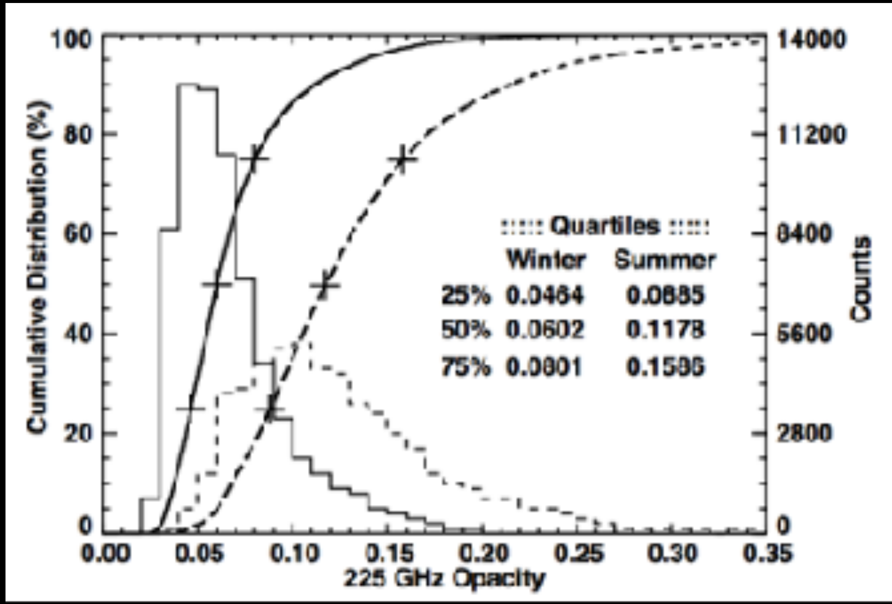


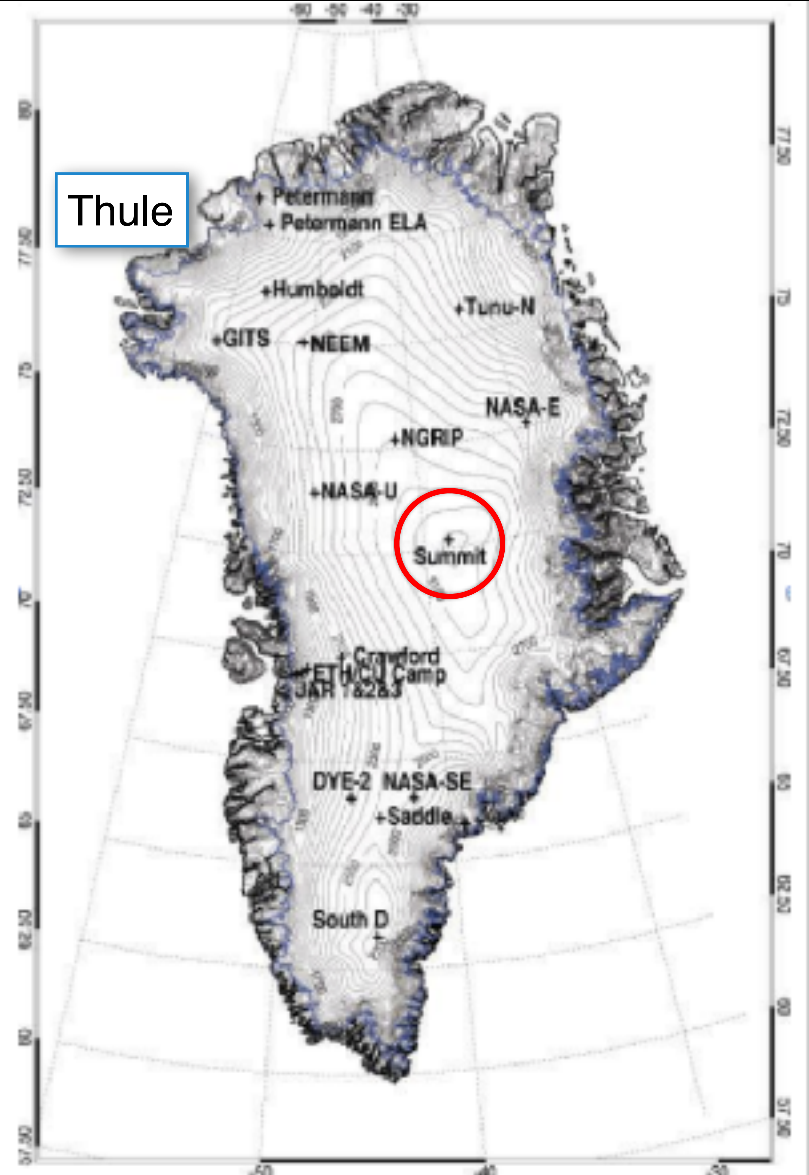
TABLE 1
COMPARISON OF 225 GHZ OPACITY QUARTILES BETWEEN THREE SITES.

Site	Season	Quartiles 25%	50%	75%
Greenland	Winter	0.046	0.060	0.080
	Summer	0.089	0.118	0.159
ALMA	Winter	0.035	0.050	0.080
	Summer	0.071	0.131	0.261
South Pole	Winter	0.041	0.048	0.057
	Summer	0.050	0.062	0.076

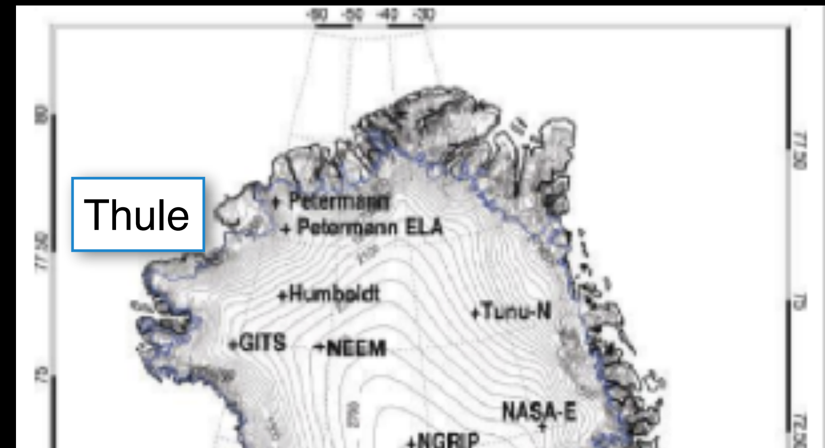
Matsushita, S. et al 2017, PASP, 129, 1

Greenland – Summit Station

- Established/operated by US NSF & Greenland Government.
  - Atmospheric and weather researches are main topics. Established in 1989.
  - N72.60º, W38.42º. Altitude: 3210m.
  - Summer: 45 people, Winter: 5 people (3 months shift)
  - Possible to carry things by flights with C-130, etc., or through land
  - Currently under expansion (Recapitalization)



Greenland – Summit Station



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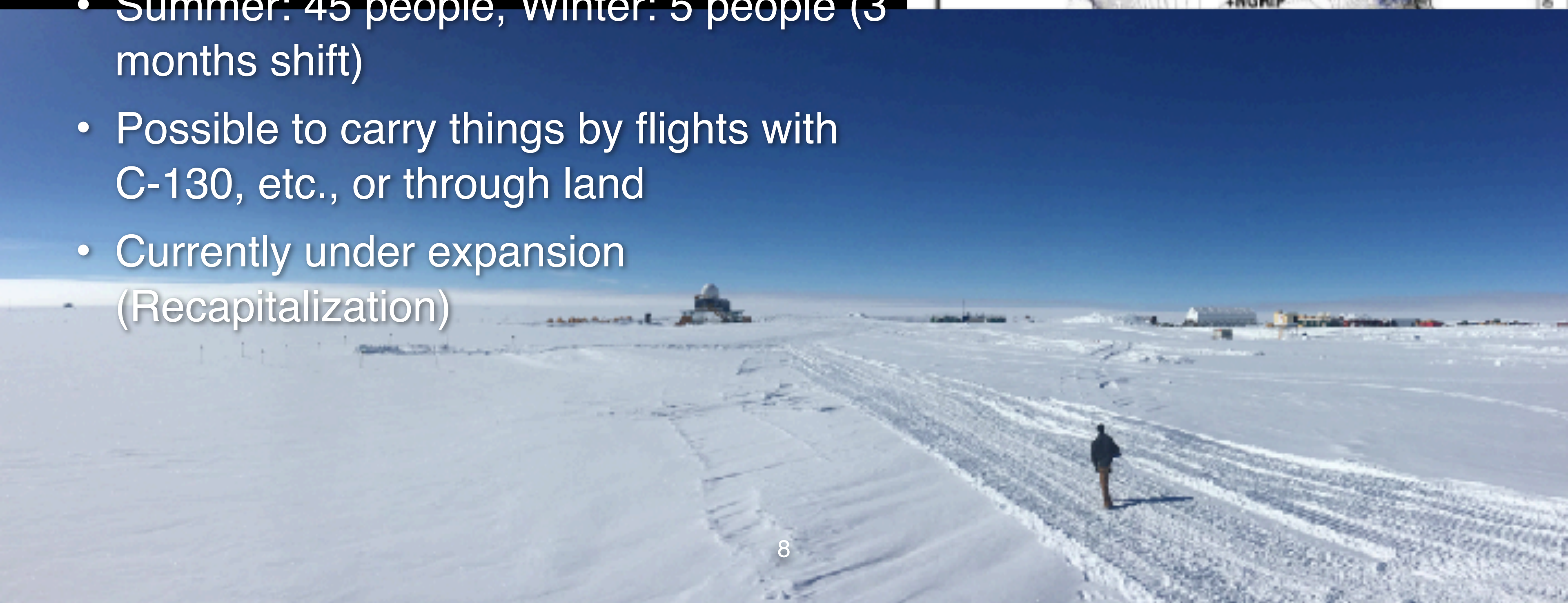


History ….


2011: ALMA Prototypes, Socorro, NM


2012: Retrofit started


2016: Pre-assembly, Norfolk, VA

History ….

2017: Assembling, Thule, Greenland


2020: In operation, Thule, Greenland

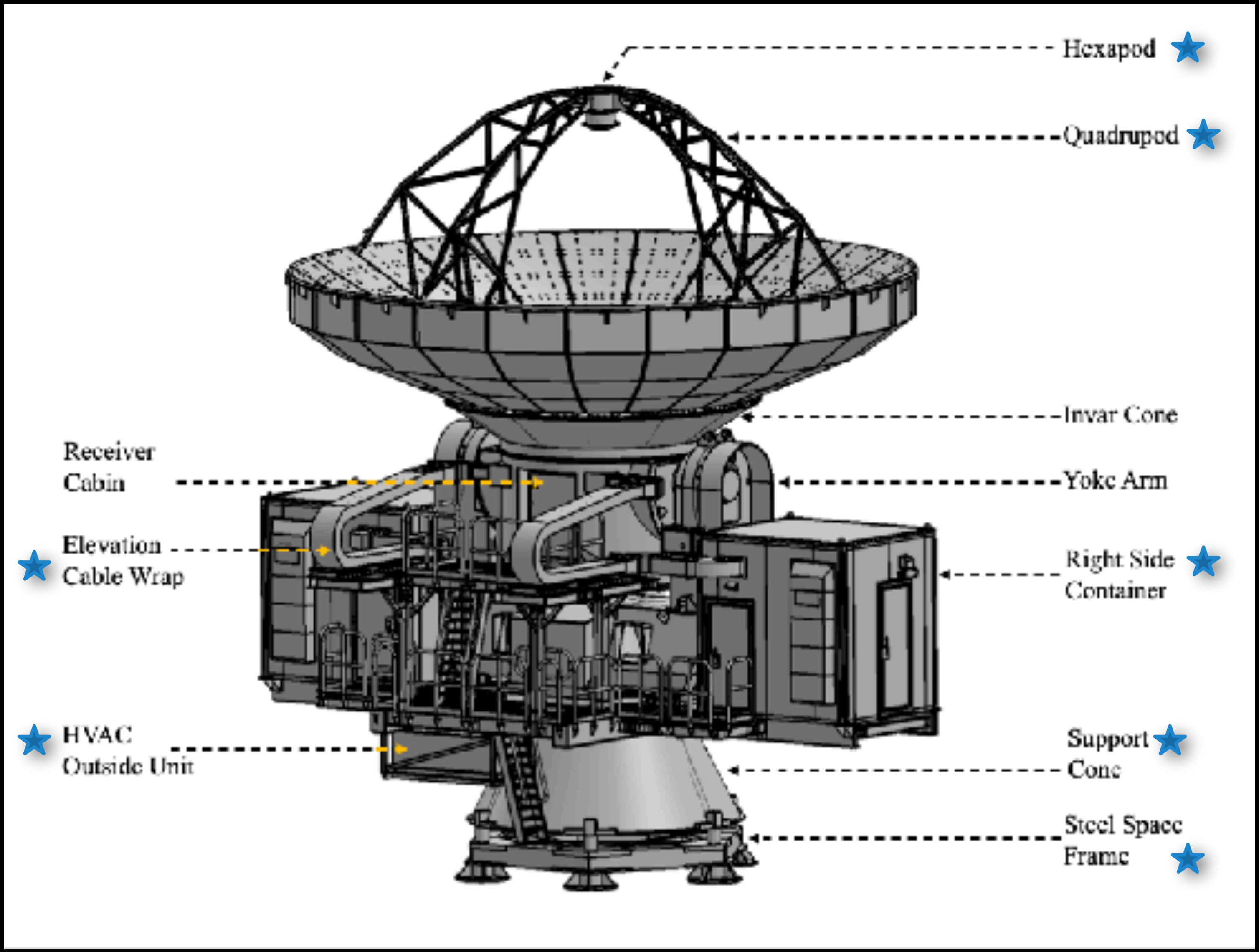
GLT Specifications

Antenna characteristics	
Keyword	Value
Primary Aperture	12.0 m
Focal Length (Primary)	4.80 m
fp / D of Primary	0.40
Secondary Aperture	0.75 m
Final f / D	8.00
Primary Illumination (Edge Taper)	12 dB
Magnification Factor	20.0
Primary Angle of Illumination	128.02°
Secondary Angle of Illumination	7.16°
Distance from Primary to 2nd Foci	6.177 m
Depth of Primary	1.875 m
Primary Vertex Hole Clear Aperture	0.75 m
Elevation axis travel range	+1.89° to +90°
Azimuth axis travel range	-180° to +360°
Total weight	112 Metric ton

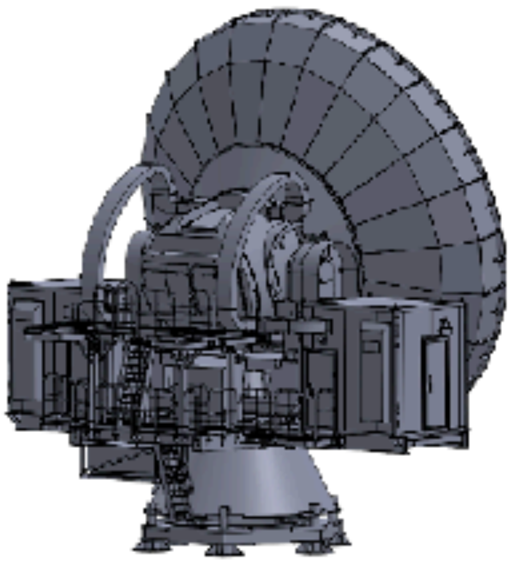
Required operating conditions on Greenland's Summit

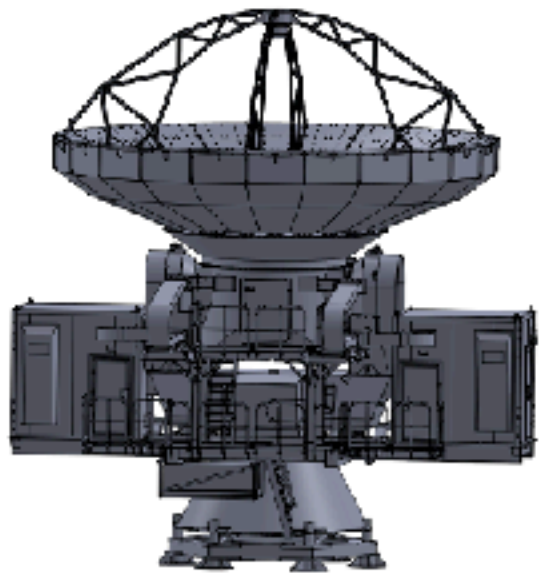
Keyword	Primary	Secondary	Survival
Ambient temperature	0 to -50 °C	-50 to -55 °C	-55 to -73 °C
Vertical temperature gradient*	+12K to -1K	+15K to -2K	N/A
Wind speed	0 to 11 m/sec	11 to 13 m/sec	55 m/sec

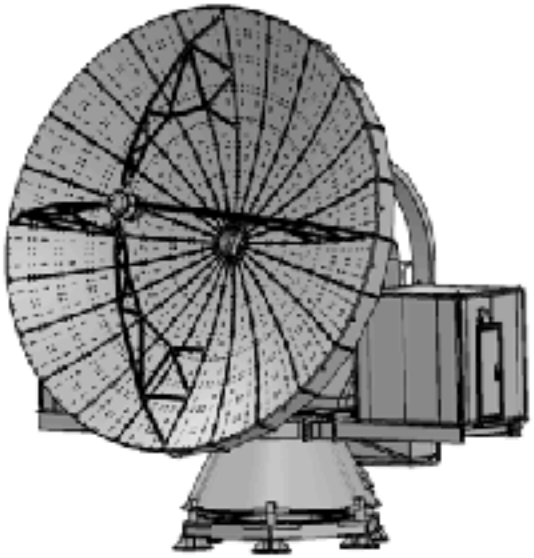
GLT Subsystems



GLT Orientations







GLT Nutator (Hexapod)

Table 3

GLT hexapod sub-reflector characteristics

Keyword	Value
Min. dynamic loading	53 kg
Dimensions	Dia. 580 mm, Ht. 613 mm
Total weight	67 kg
Interface material	Invar
Movement in x and y axis	
- Distance	+/- 5 mm from center
- Slewing Mode	Less than 0.5 mm/sec
- Collimation mode	Min. steps of 20 µm, 10 µm differential accuracy
Movement in z axis (optical axis)	
- Distance	+/- 10 mm from center
- Slewing Mode	Less than 0.5 mm/sec
- Focus adjustment	Min. steps of 20 µm, 5 µm differential accuracy
- Focus switching	Perform cycles up to +1.5 mm and -1.5 mm with repeatability of +/- 20 µm
Nutating	
- Chopping Range	10 arcmin maximum
- Accuracy	1.3 arcsec
- Direction	Any directions
- Chopping Freq	2 Hz
- Chopping mode	Two-position chopping
- Settling time	Less than 50 ms

-150 C

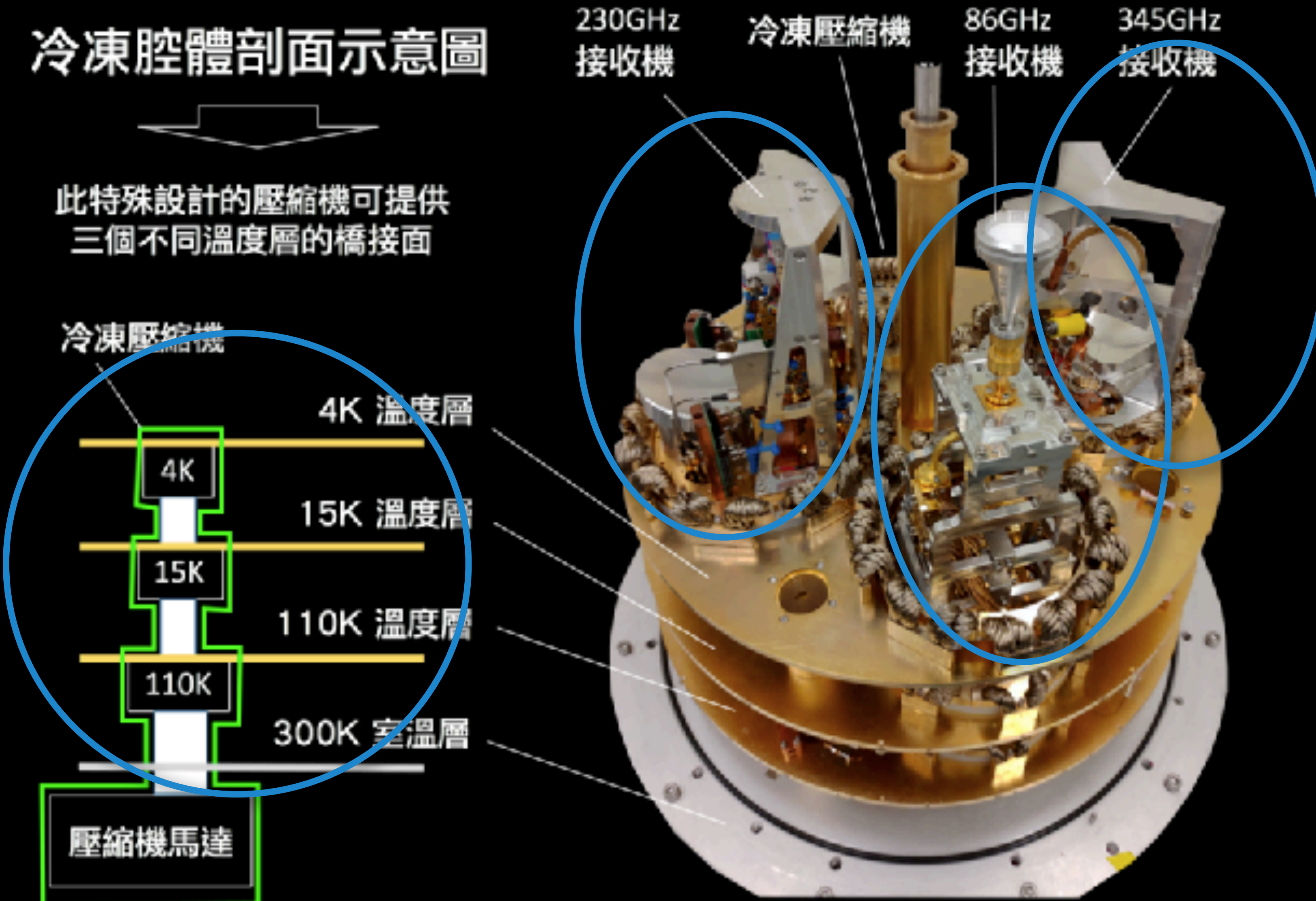
GLT VLBI Receiver

Single cryostat, three receiver cartridges

Keyword	Rx86	Rx230	Rx345
Origin	ASIAA	OPU	IRAM
Polarization	Dual Circular	Dual Circular	Dual Linear
RF freq. range	84 – 96	213 – 231	275 – 373
LO freq. range	80 – 88	221 – 223	283 – 365
1st stage detector	MMIC	SIS	SIS
Mixing scheme	USB after 1st mixer	2SB	2SB
# of IF channel	2	4	4
IF (GHz)	4 – 8	4 – 8	4 – 8
VLBI LO freq. (GHz)	80.6	221.1	342.6
TSSB (K) 80% LO range (All)	90	70 (110)	147 (219)

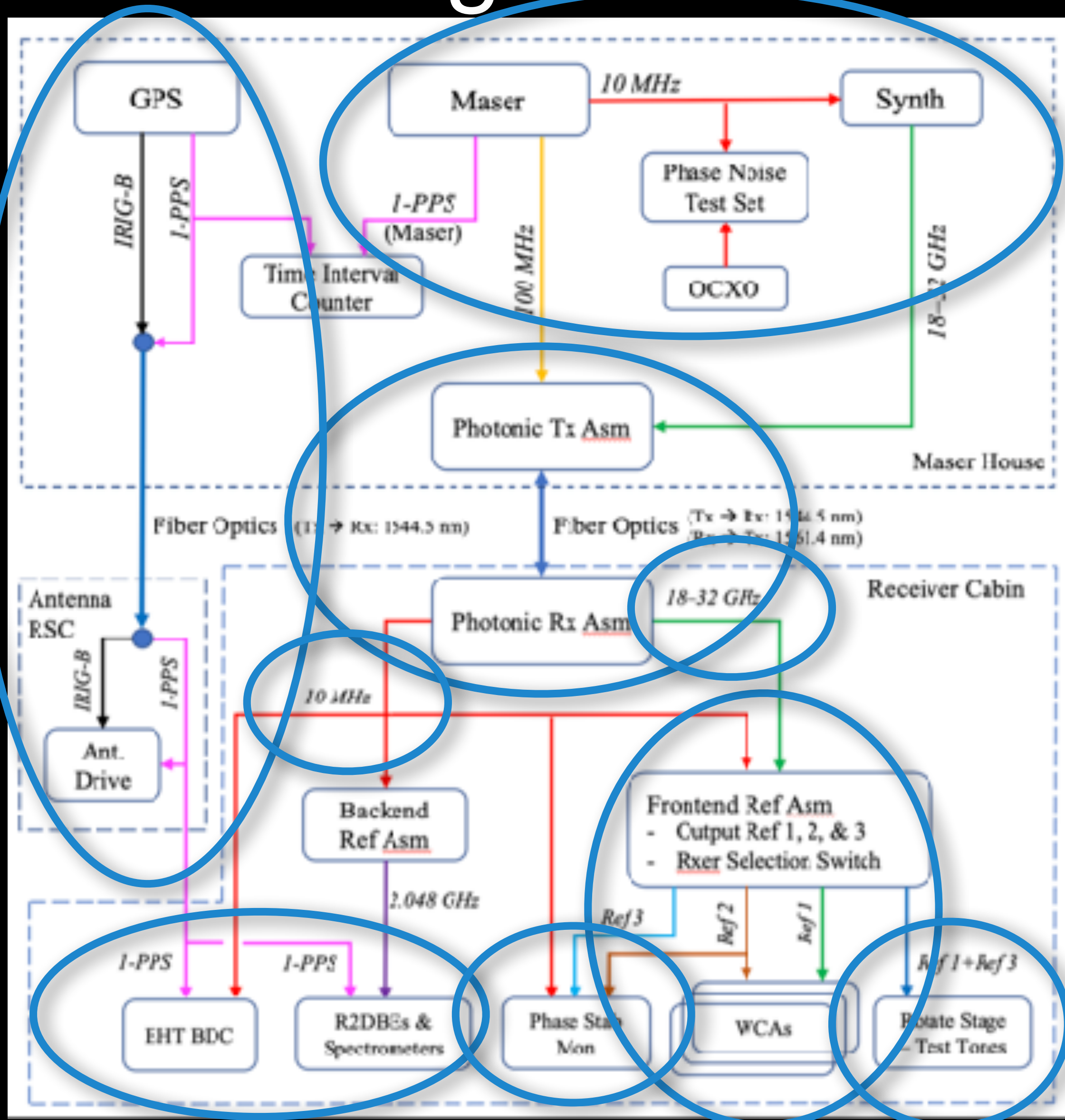
First Light

GLT Cryostat (2^{nd} Version)

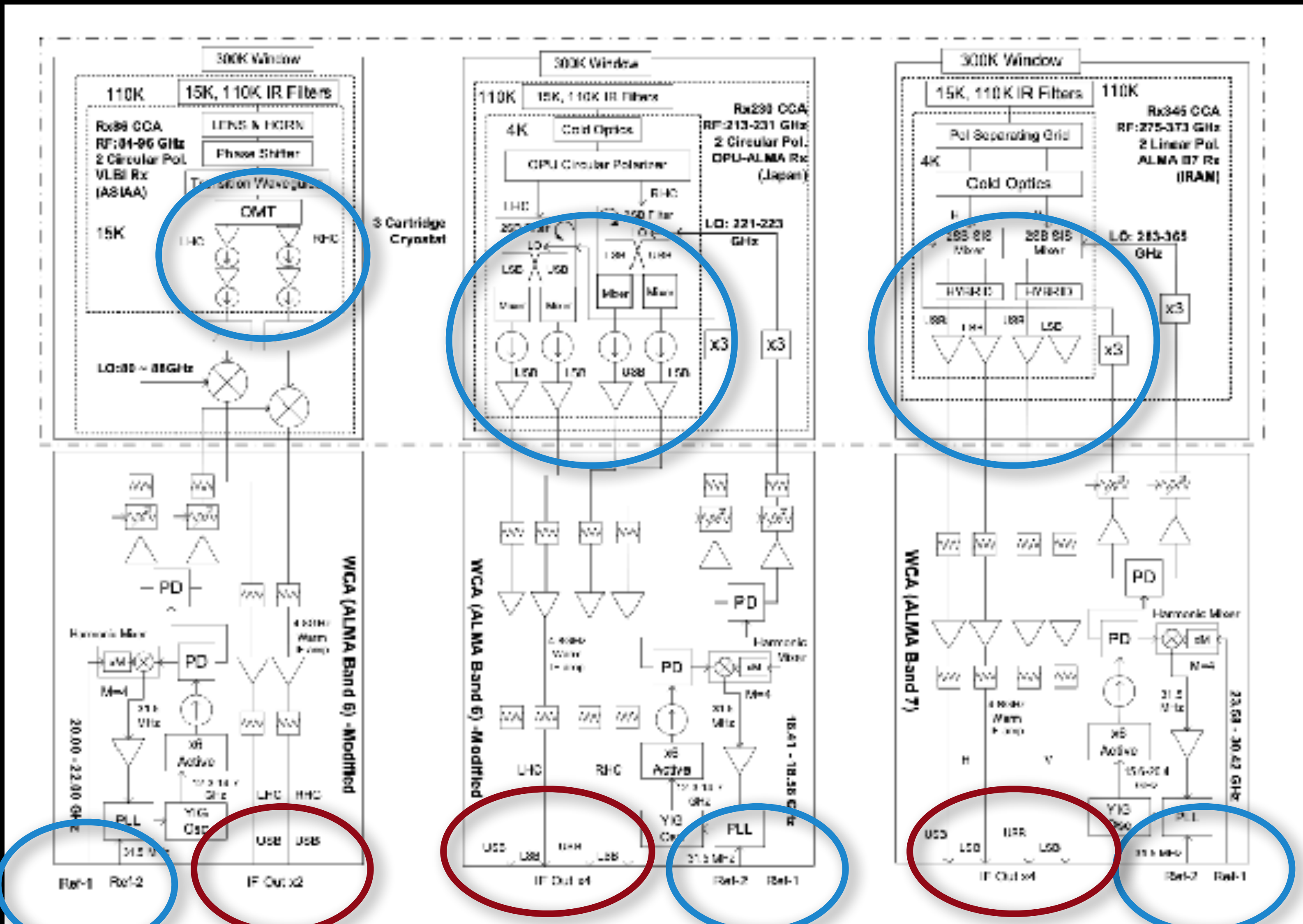


JCMT Installation

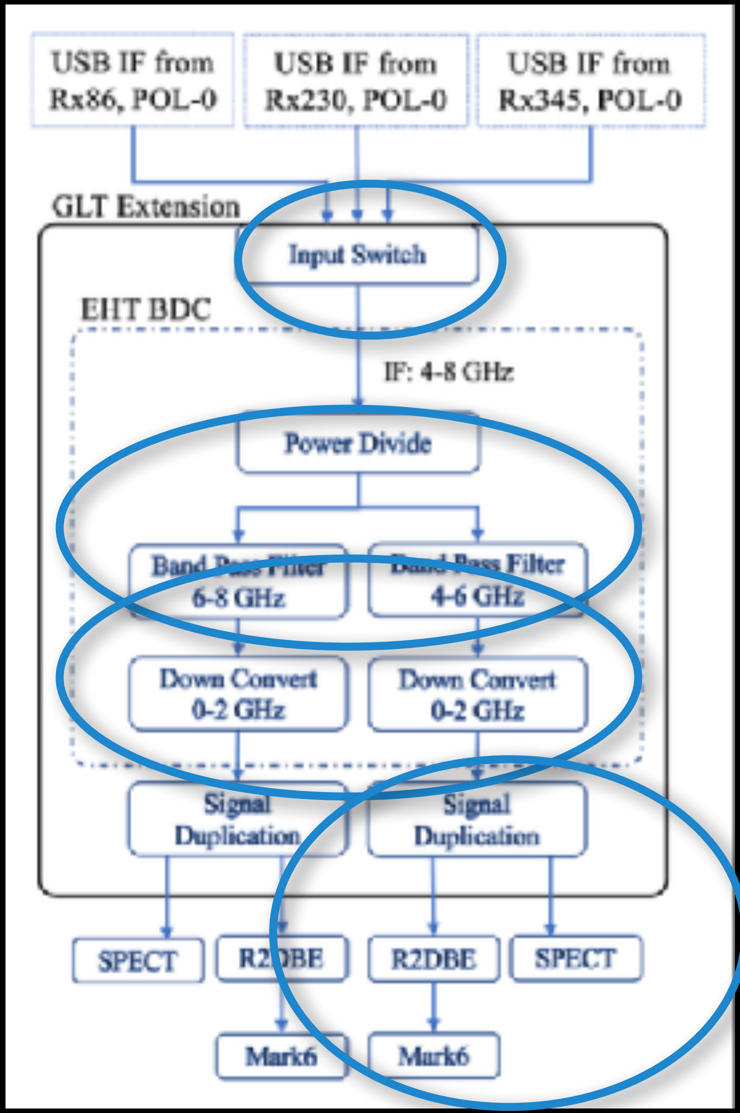
Reference Signals Distribution



Receiver LO/IF Distribution



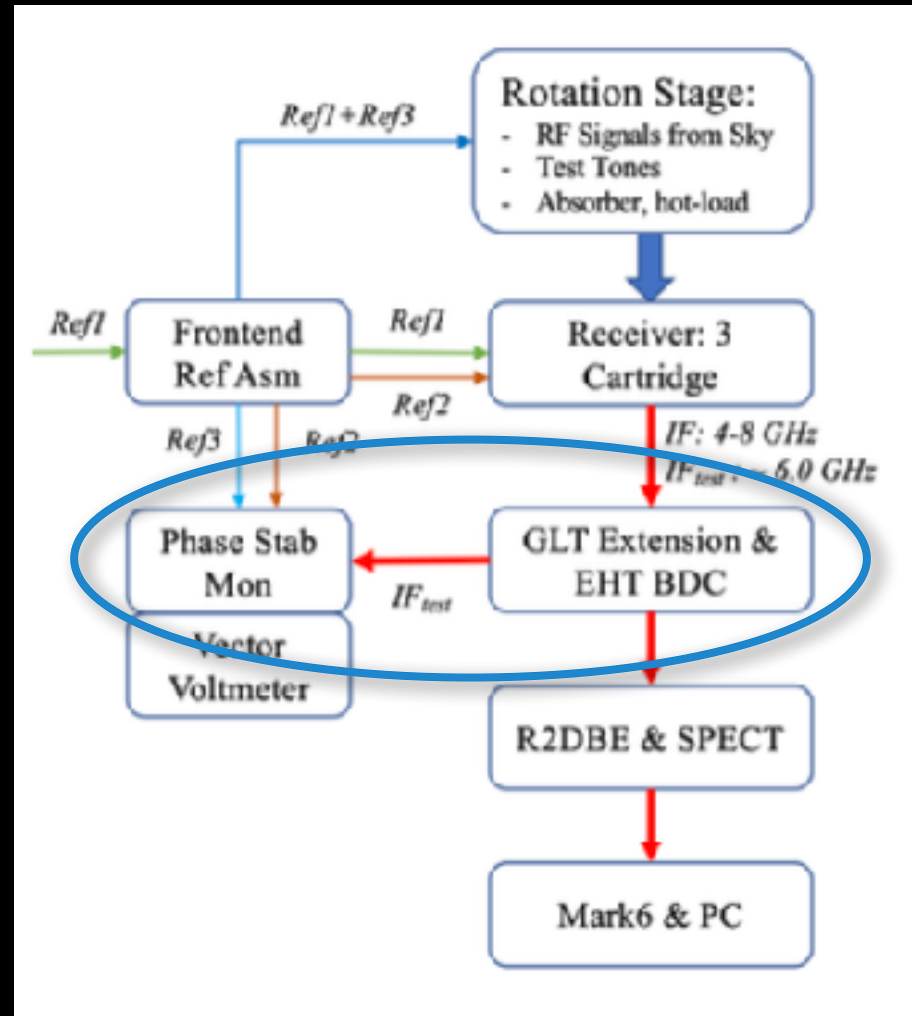
IF/Baseband Processing



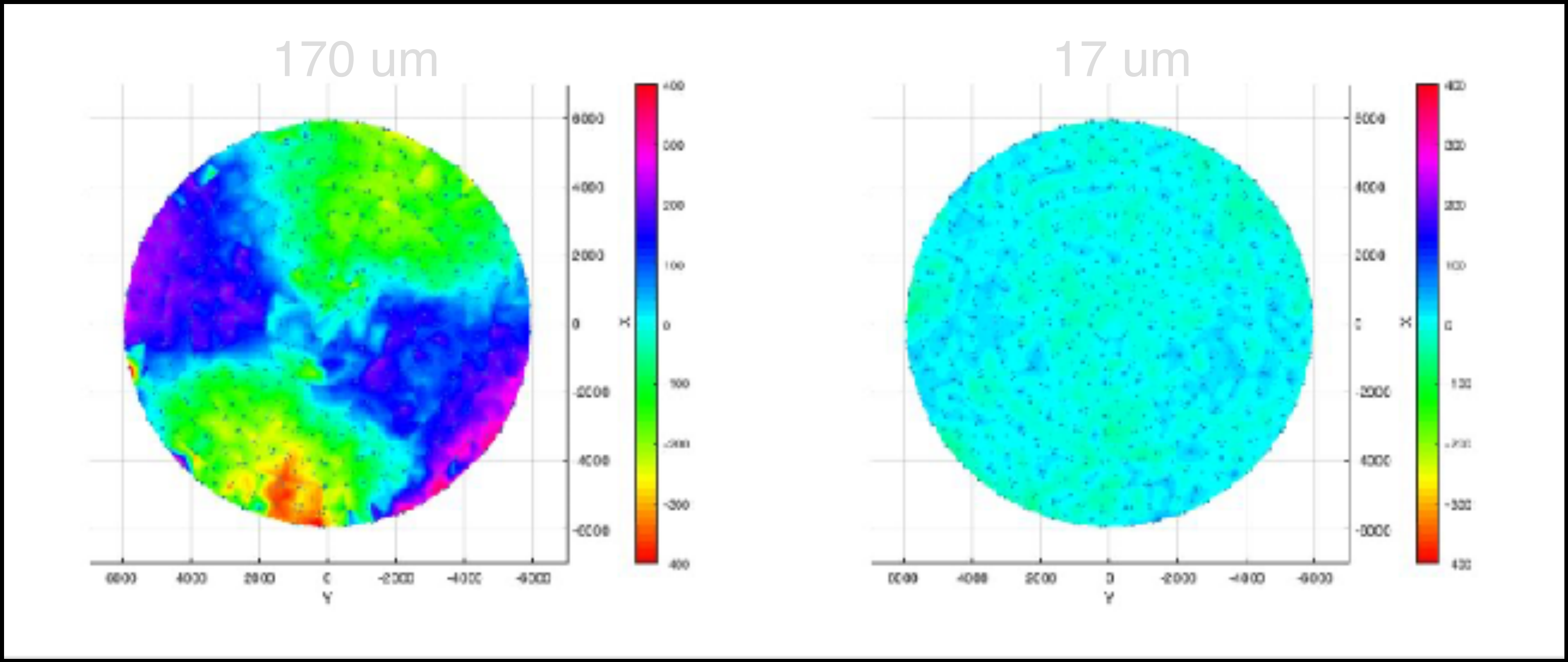
- Extended Block Down Converter x 2
- Input switch select receiver channel
- IF: 4-8 GHz —> 2 blocks of 0-2 GHz
- Duplication of signals; one sent to R2DBEs, and one to spectrimeters
- R2DBE digitizes the blocks and sent to Mark6 recoder

Test Tones Gen/Processing

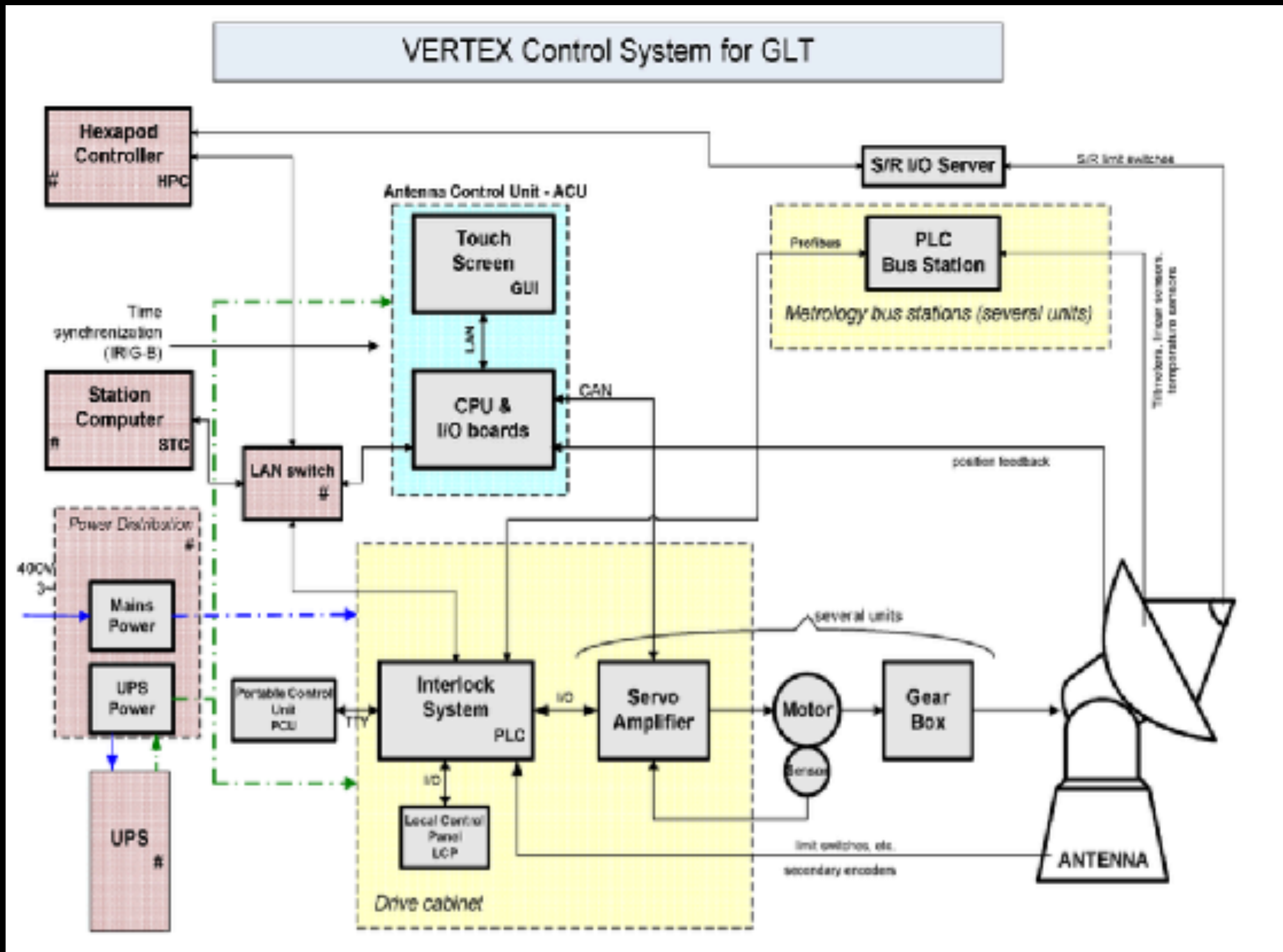
- Critical setup for VLBI observations
- Tone sources for all three receiver cartridges
- When needed, a rotation arm will move the source into the signal beam
- Designed to generate a tone ~ 6.0 GHz
- Compare the signal with reference and ensure stable phase
-



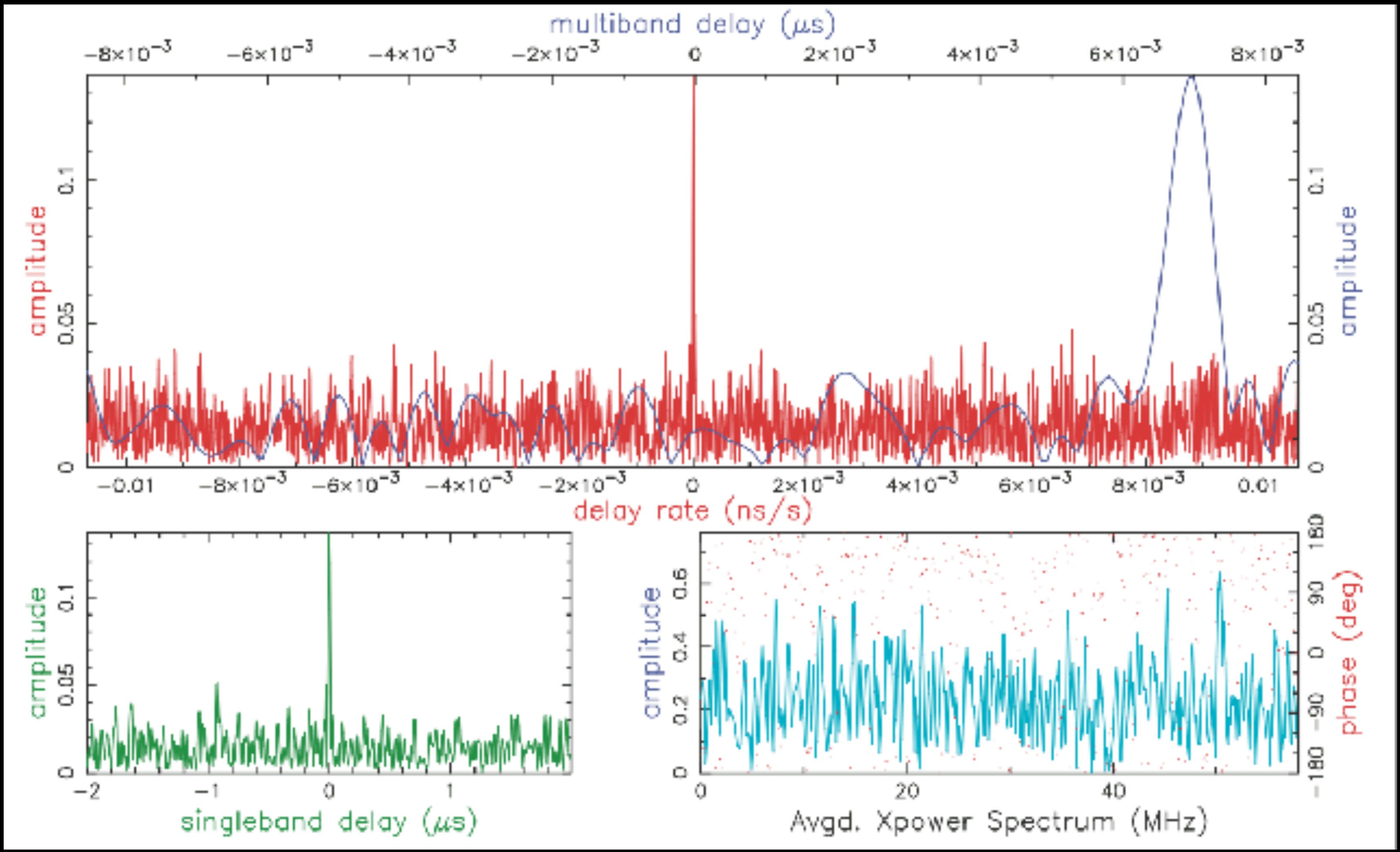
Photogrammetry



Antenna Control System

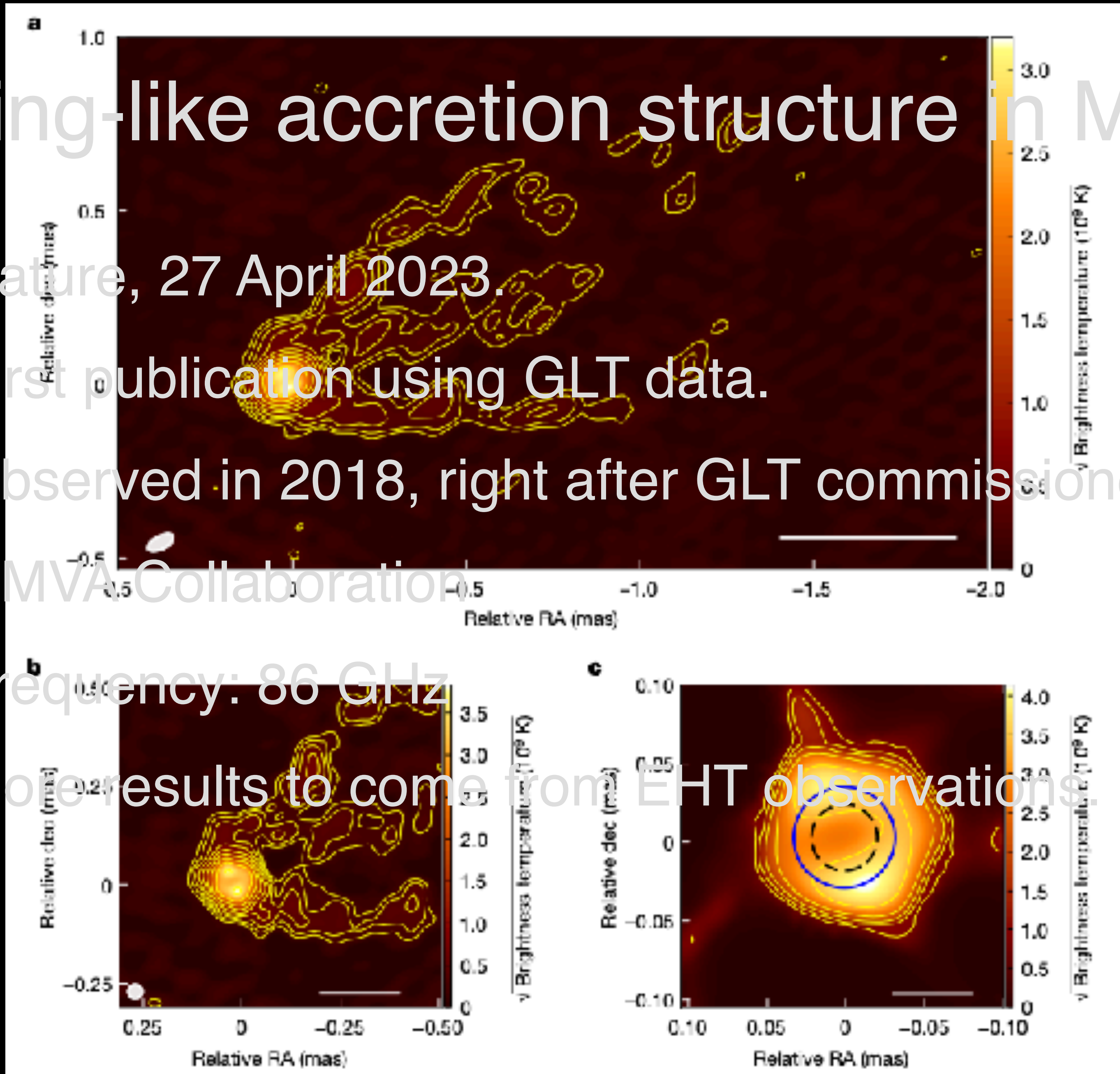


Fringe Detection with ALMA 2018



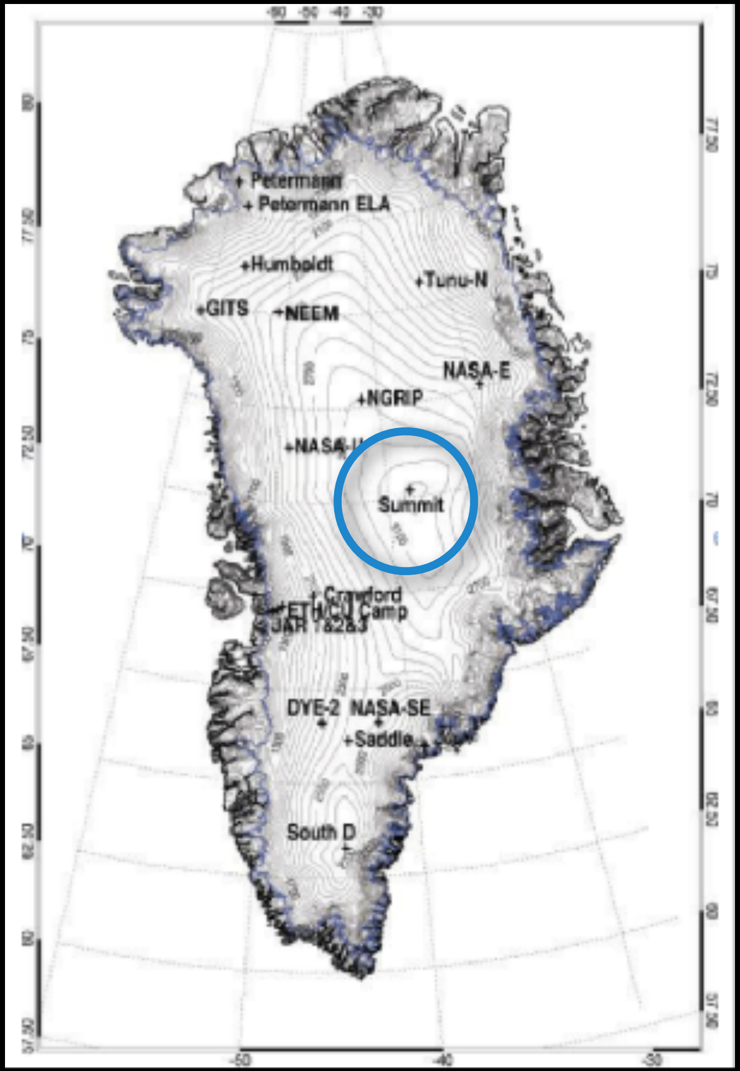
A ring-like accretion structure in M87

- Nature, 27 April 2023.
- First publication using GLT data.
- Observed in 2018, right after GLT commissioned.
- GMVA Collaboration
- Frequency: 86 GHz
- More results to come from EHT observations.



Moving to Summit

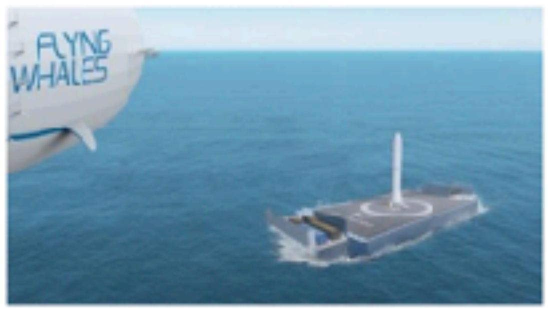
- A difficult, dangerous, and expensive journey
- High operation cost on Summit
- Difficult to access; summer or winter
- But doable nevertheless
- Highest resolution achievable from ground
- VLBI at 690 GHz: Black hole photon rings



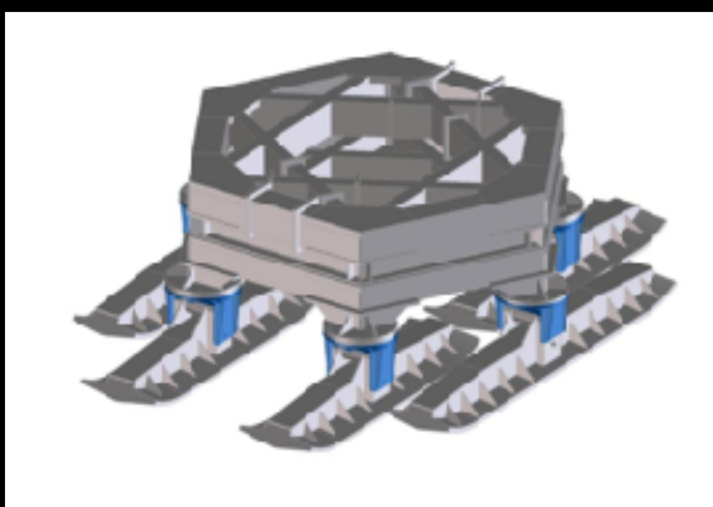

Johnson
Tashun
Ming-Tang

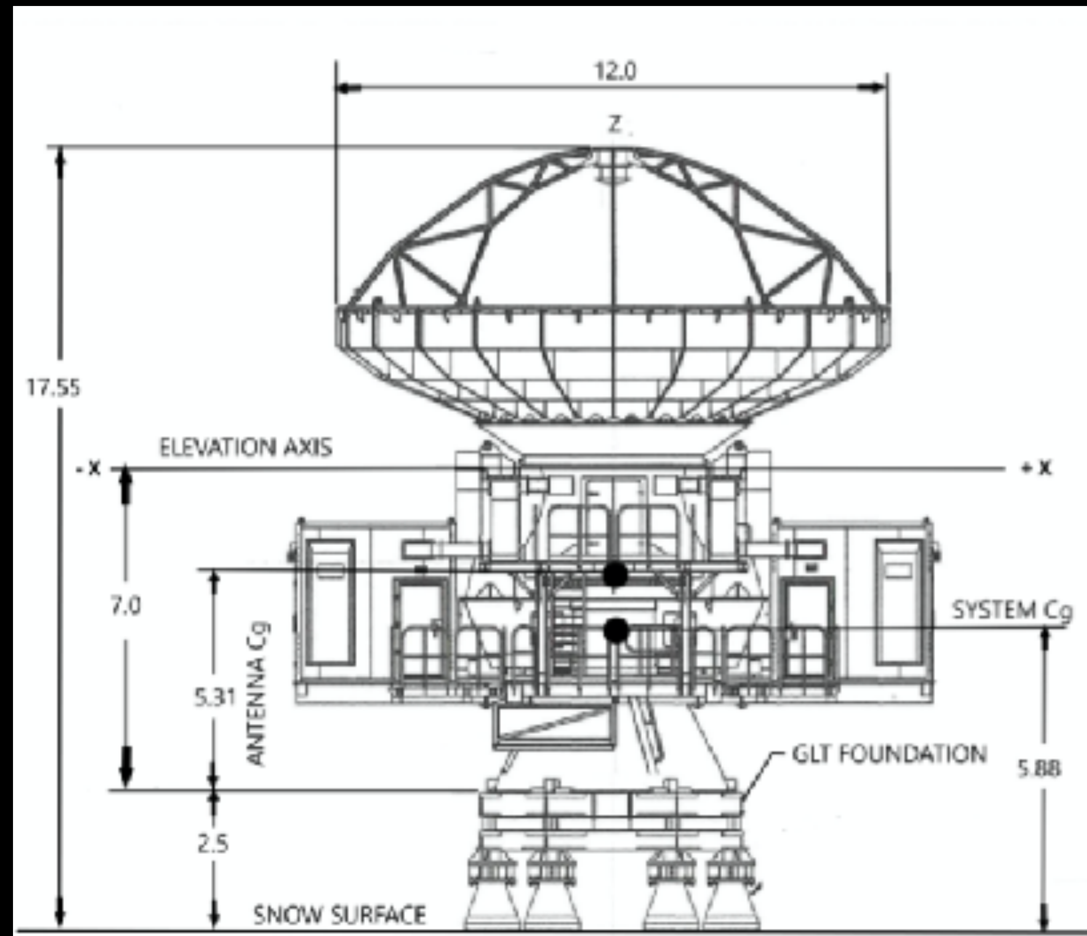
Curtesy of JP Steffensen @ EGRIP


FLYING
WHALES


FLYING
WHALES

GLT on Skis




12.0
Z
17.55
ELEVATION AXIS
-X
+X
7.0
SYSTEM Cg
5.31
ANTENNA Cg
GLT FOUNDATION
5.88
2.5
SNOW SURFACE

Summary

- One and only submm radio telescope in the polar region
- A critical station for submm VLBI observations
- For optimal outcome: Move to Summit Station
- However difficult: Ultimost resolution for black hole images (from ground)

https://doi.org/10.1088/1538-3873/acf072

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