Sub-Orbital Landscape

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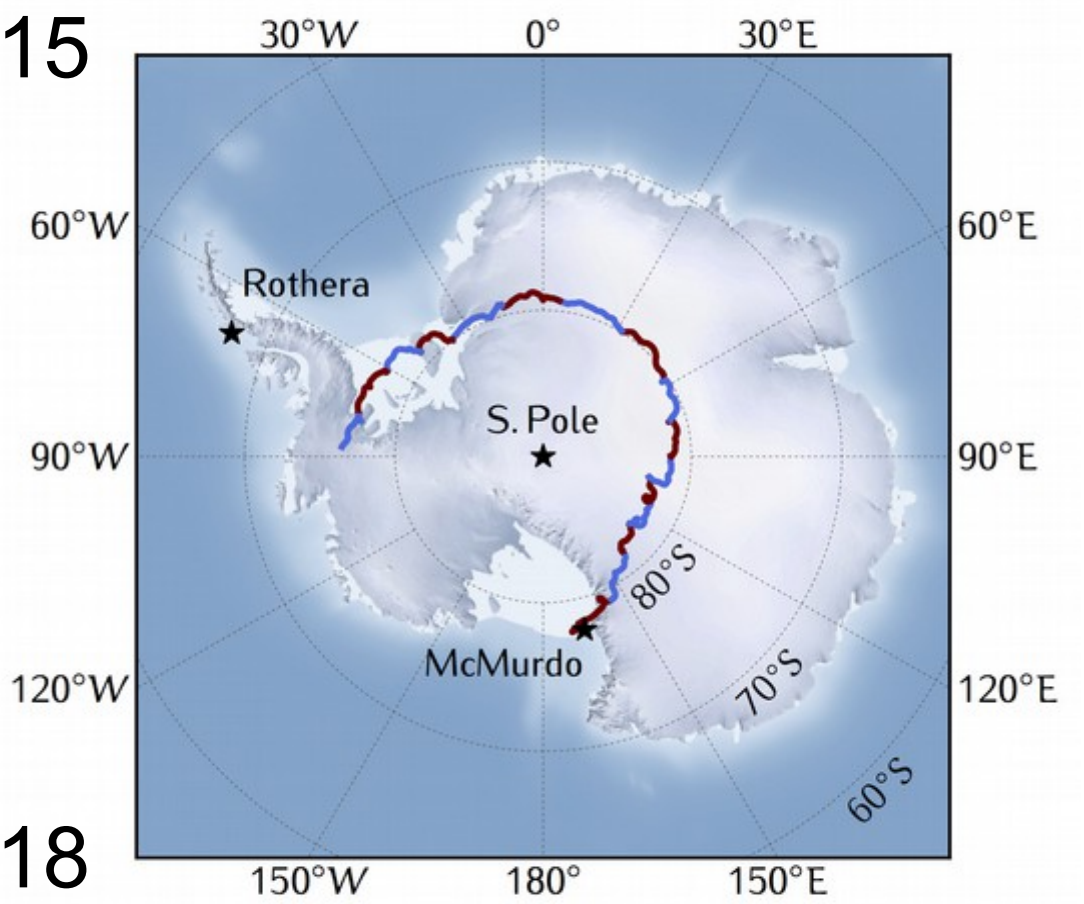
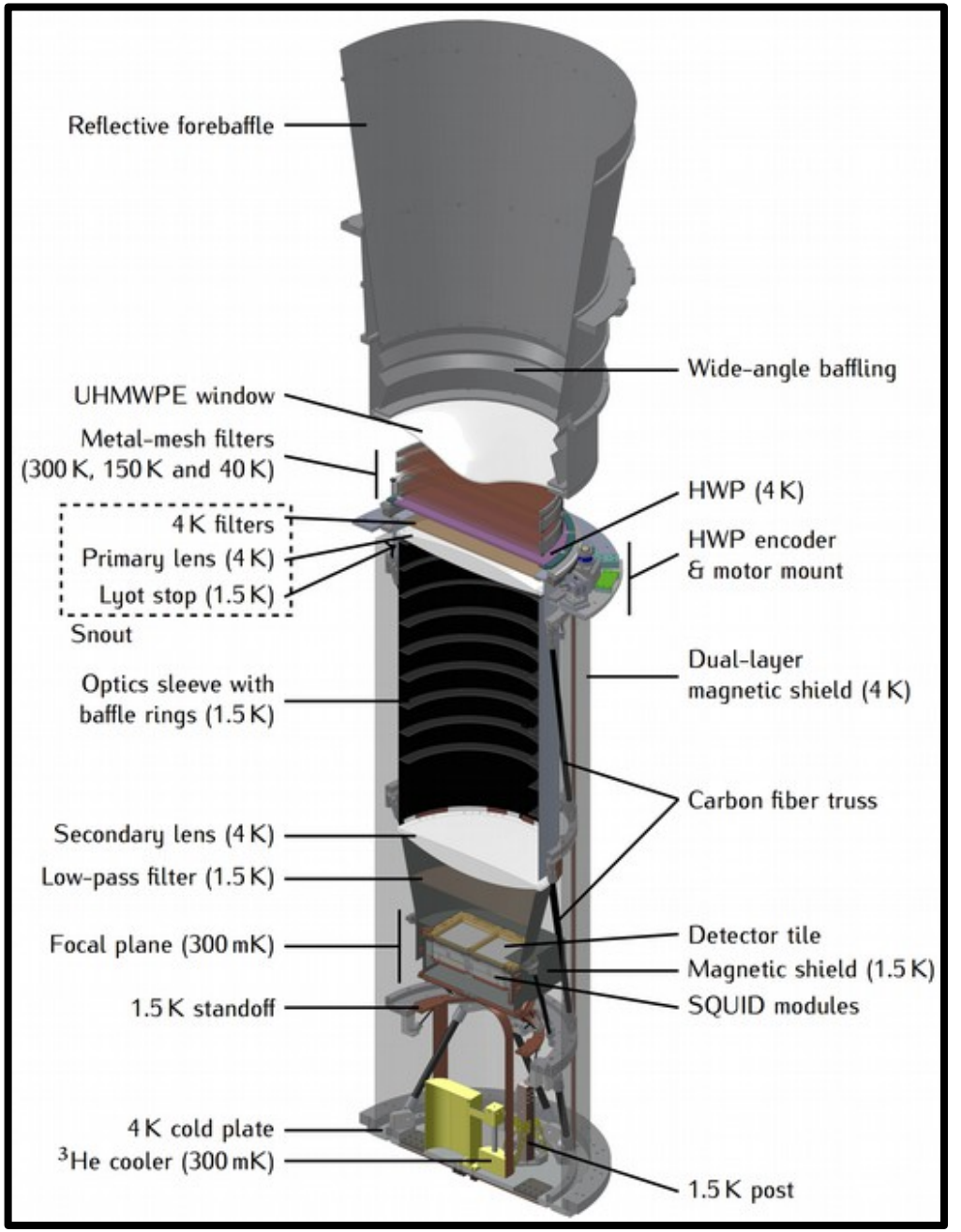
Spider Flight Summary (from S. Rahlin)

- Launched January 1, 2015
- 16 days at float
- 1.6 TB data
- Data recovered, February 2015
- Hardware recovered November 2015
- Next flight December 2018



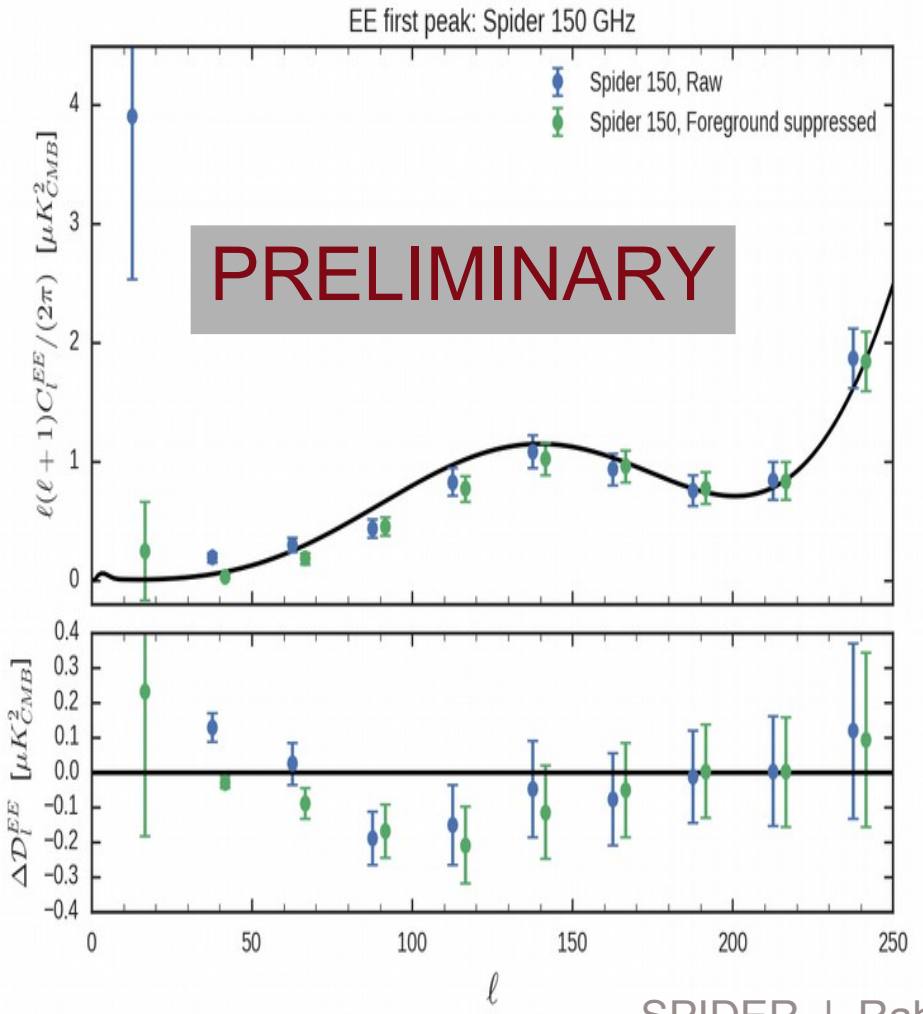
Spider Receiver (by S. Rahlin)

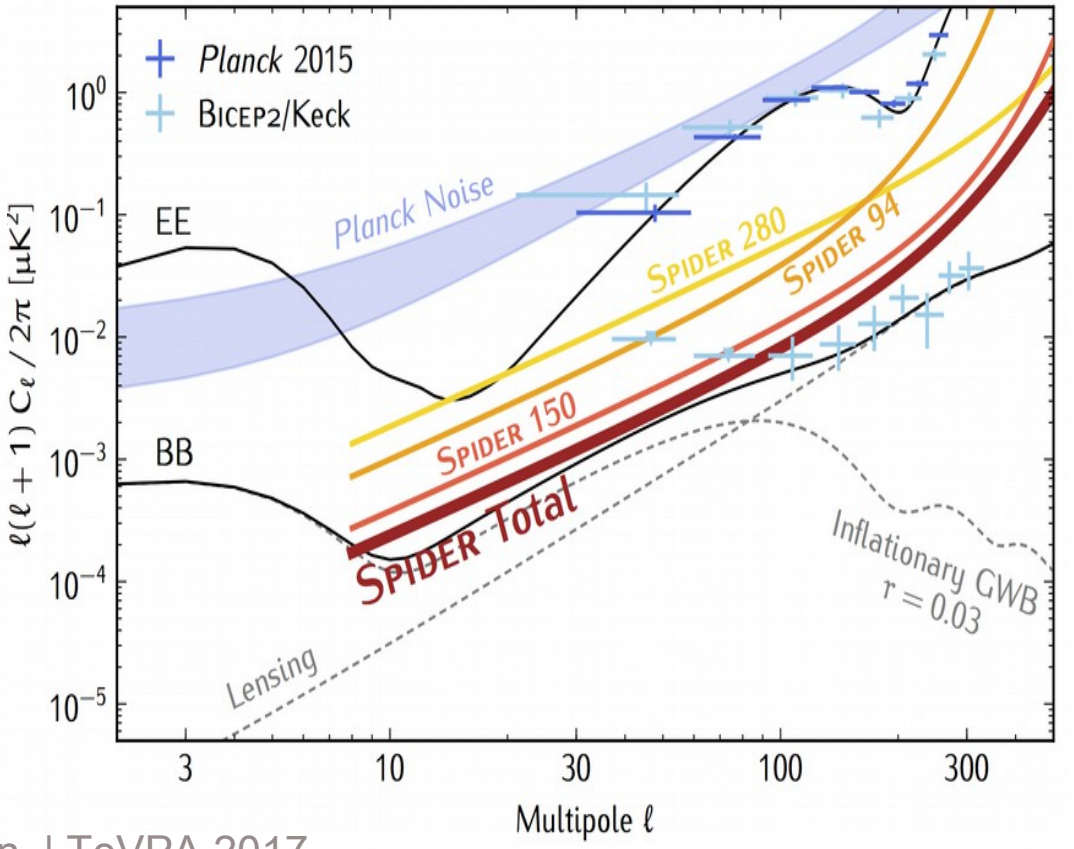
SPIDER | Rahlin | TeVPA 2017



SPIDER-2 Development (by S. Rahlin)

- Evidence of foregrounds at large angular scales
- 280 GHz receivers to characterize Galactic dust
- Expected sensitivity after two flights:





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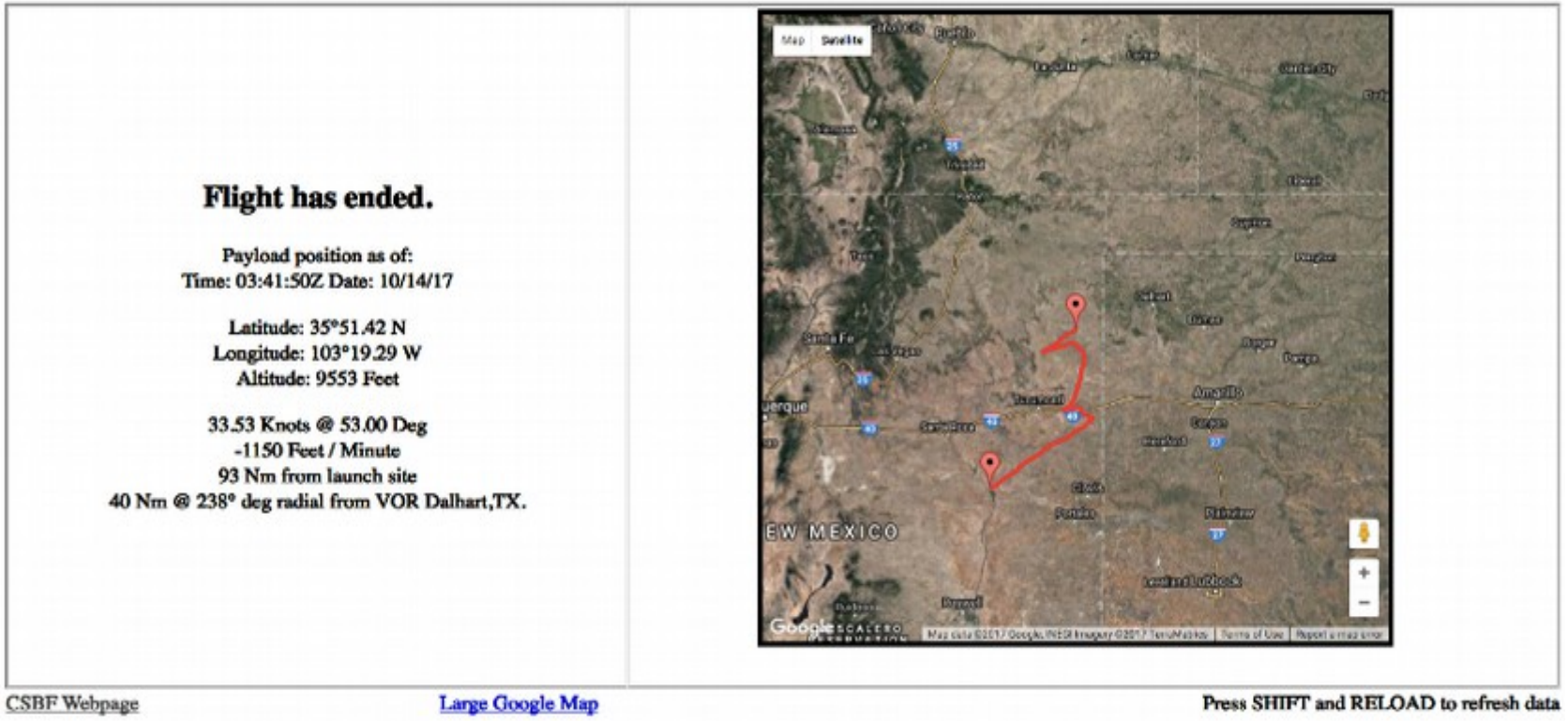
PIPER (asd.gsfc.nasa.gov/piper/)

1st engineering flight was October 13

- Landing was a bit rough (http://stratocat.com.ar/news20171101-e.htm)

- 200, 270, 350, 600 GHz
- ~5000 NIST detectors
- Multiple single-night flights to cover multiple frequencies



GSFC (PI), Hopkins, NIST
UBC, Cardiff, Villanova, Ames, College Park MD, Stanford, Wyle STE, Michigan, ADNET

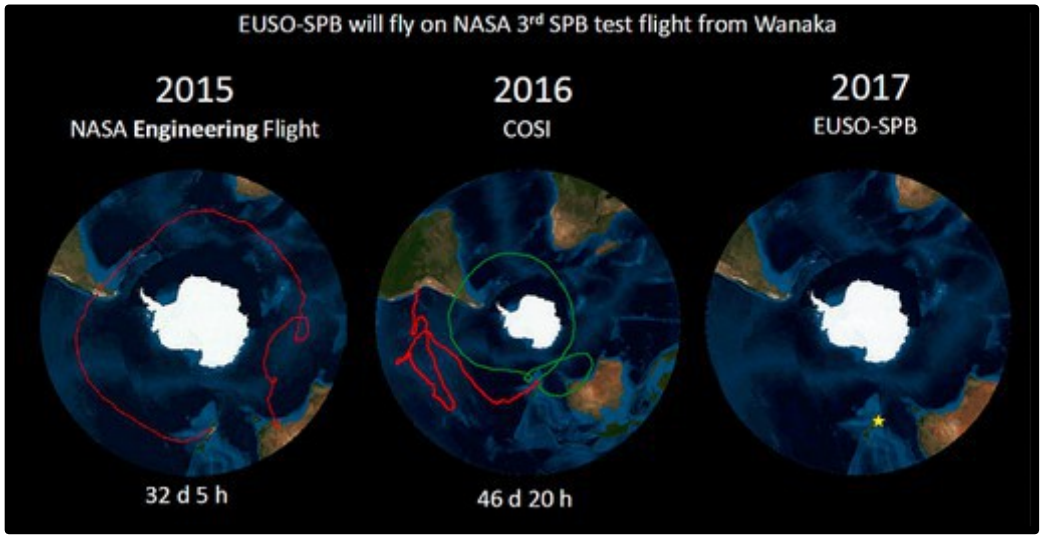
Super-Pressure Balloons (SPB~ULDB)

There have now been 3 SPB flights. The first two lasted about a month and a month-and-a-half.

These have weight and power constraints that are hard to meet (for the CMB)

EUSO-SPB (not CMB!) launched in April and got a couple of weeks of data before falling into the sea.

I'm told that they have been given support for another flight



http://astroserve.mines.edu/euso_spb/FlightPath.html

http://stratocat.com.ar/spb17_map_final.jpg

Future Balloon Landscape

- SWIPE is the high-frequency part of LSPE, led by Paolo de Bernardis at La Sapienza, Rome.
- Olimpo: An SZ experiment which has been waiting for a northern launch for years. Also led by Paolo de Bernardis at La Sapienza, Rome.
- BFore: a ULDB CMB+Foreground mission, has not been fully funded, but got some support for development.
- EBEX: was not selected
- There are also high-frequency astrophysics balloon missions such as BLAST & PILOT

Fielded Anisotropy Experiments

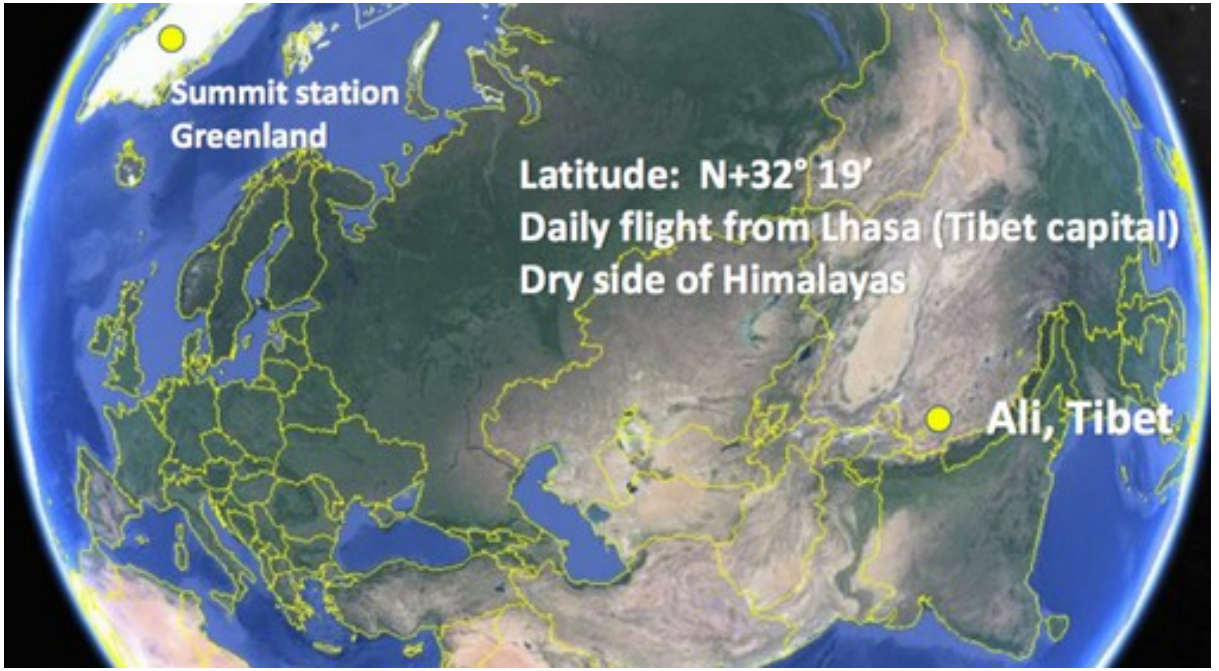
- Small Aperture/Pole
  - BICEP/Keck: Adding more cameras/detectors and going to higher frequencies
- Small Aperature/Chile
  - CLASS commissioning at ν<90 GHz

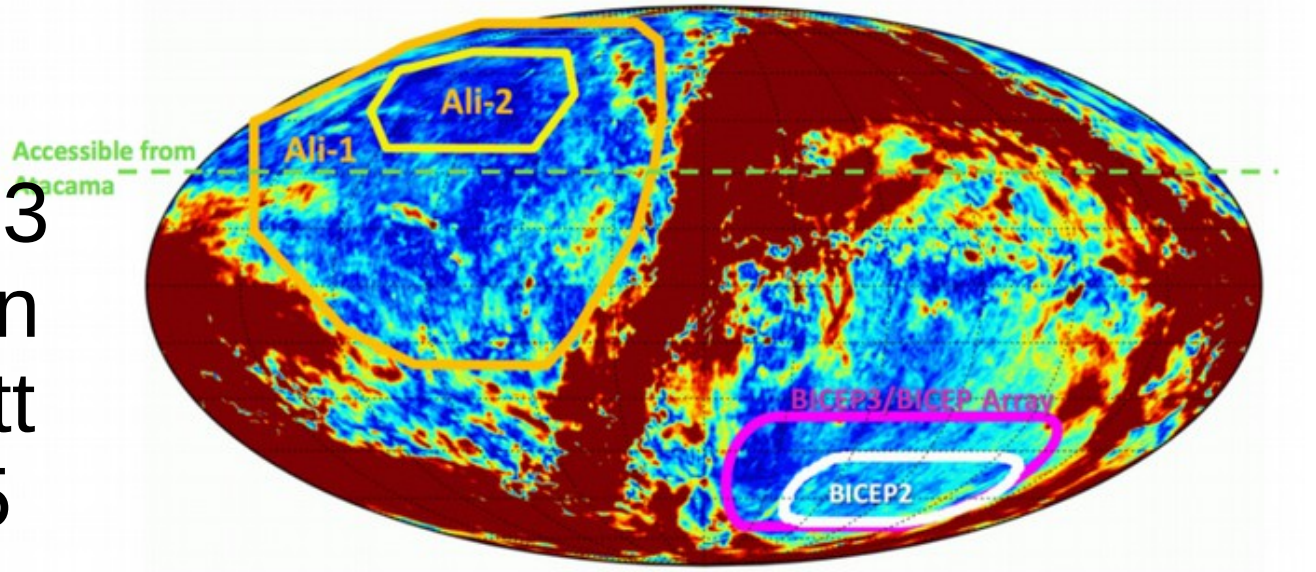
Tenerife: QUIJOTE

- Large Aperture/Pole
  - South Pole Telescope has 15000 detectors on the telescope now
- Large Aperture/Chile
  - ACT
  - Simons Array

Other Ground-Based Locations

- Ali would be in Tibet mountains with a possibility of 6000 m
- Sino-SLAC collaboration
- See C.-L. Kuo presentation at : (https://indico.in2p3.fr/event/14661/contributions/19261/attachments/43751/54261/KuoV2.pdf)





1. There will be lots of lessons learned with better statistics
2. Staged wedding cake strategy may be advantageous (e.g. Kovetz & Kamionkowski PRD 91, 081303R,2015)

European Ground

- COSMO: New, small, spectrum measurement at Dome C. Silvia Masi
- KISS: A low-resolution, KIDs, mm spectrometer under construction to field at Tenerife in 2018
- NIKA2: Just finished commissioning the first 1000+ KIDs focal plane as a facility instrument at the IRAM 30 m
- GroundBIRD@Tenerife
- QUBIC: Observations in Argentina with 1 TES array next year. Upgrade to all TES arrays in early 2019.
- QUIJOTE: 10-20 GHz running since 2012. 30 GHz commissioning now. 40 GHz next year.
- STRIP: Low-frequency part of LSPE. It was originally going to fly on a balloon, but has now been re-designed to observe from Tenerife.

CMB Stage IV

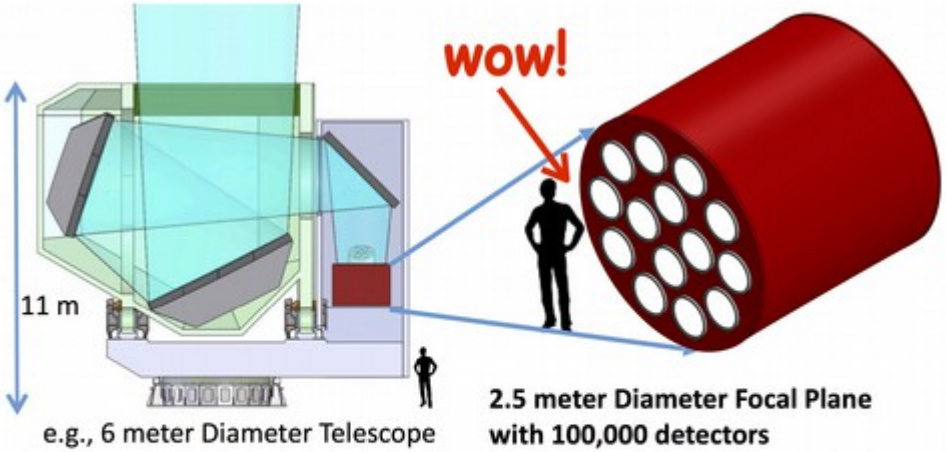
The current S4 thinking is to have a modular design. Here is Europe some of us are hoping that we can provide some of these modules.

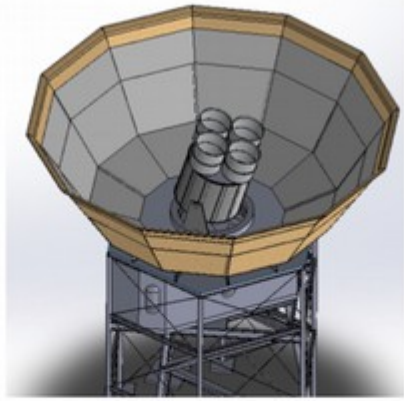
Graphic from John Carlstrom

CMB-S4
Next Generation CMB Experiment

CMB-S4 concept

- One collaboration, one project, with two sites: South Pole and Atacama, Chile
- Small and large telescopes for B-mode, de-lensing, high-ℓ cosmic structure science
- 500,000 detectors (300k on 3 large telescopes; 200k on 14 small telescopes)
- Order 8 frequency bands for CMB and foreground mitigation on small telescopes
- Two surveys: 4 yr deep B-mode w/ de-lensing (f_{sky} ~ few %)
  7 yr broad for N_{eff} and cosmic structure science (f_{sky} = 40%)





High resolution Science + de-lensing:
300,000 detectors on 3 large telescopes

Figure from Simons Obs, Mark Devlin / Mike Niemack

Low resolution B-mode Science:
200,000 det. on 14 small telescopes

Figure from BICEP Array

https://indico.in2p3.fr/event/14661/contributions/19246/attachments/43767/54161/Carlstrom_CMB-S4_Update.pdf

CMB Stage-IV

- r & N_{eff} will be the design drivers
  - But it will still do other work
- 7 years construction
- 4/7 years observation
- ~1-2 uK arcminute
- Cost ~$412M

From S4CDT Report

Science	Item	Frequency [GHz] 20	30	40	85	95	145	155	220	270	Total
r	**14 x 0.5-m cameras**										
	# detectors	. . .	260	470	17 k	21 k	18 k	21 k	34 k	54 k	168 k
	Angular resolution [FWHM]		77′	58′	27′	24′	16′	15′	11′	8.′5	
	1 x 6-m telescope										
	# detectors	130	250	500	. . .	25 k	25 k	. . .	8.7 k	8.7 k	68 k
	Angular resolution [FWHM]	11′	7.′0	5.′2	. . .	2.′2	1.′4	. . .	1.′0	0.′8	
$N_{\rm eff}$											
	2 x 6-m telescopes										
	# detectors	290	640	1.1 k	. . .	50 k	50 k	. . .	17 k	17 k	136 k
	Angular resolution [FWHM]	11′	7.′0	5.′2	. . .	2.′2	1.′4	. . .	1.′0	0.′8	