Cosmology from the Stratosphere

measurements of primordial gravitational waves and gravitational lensing from near space

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Nordita

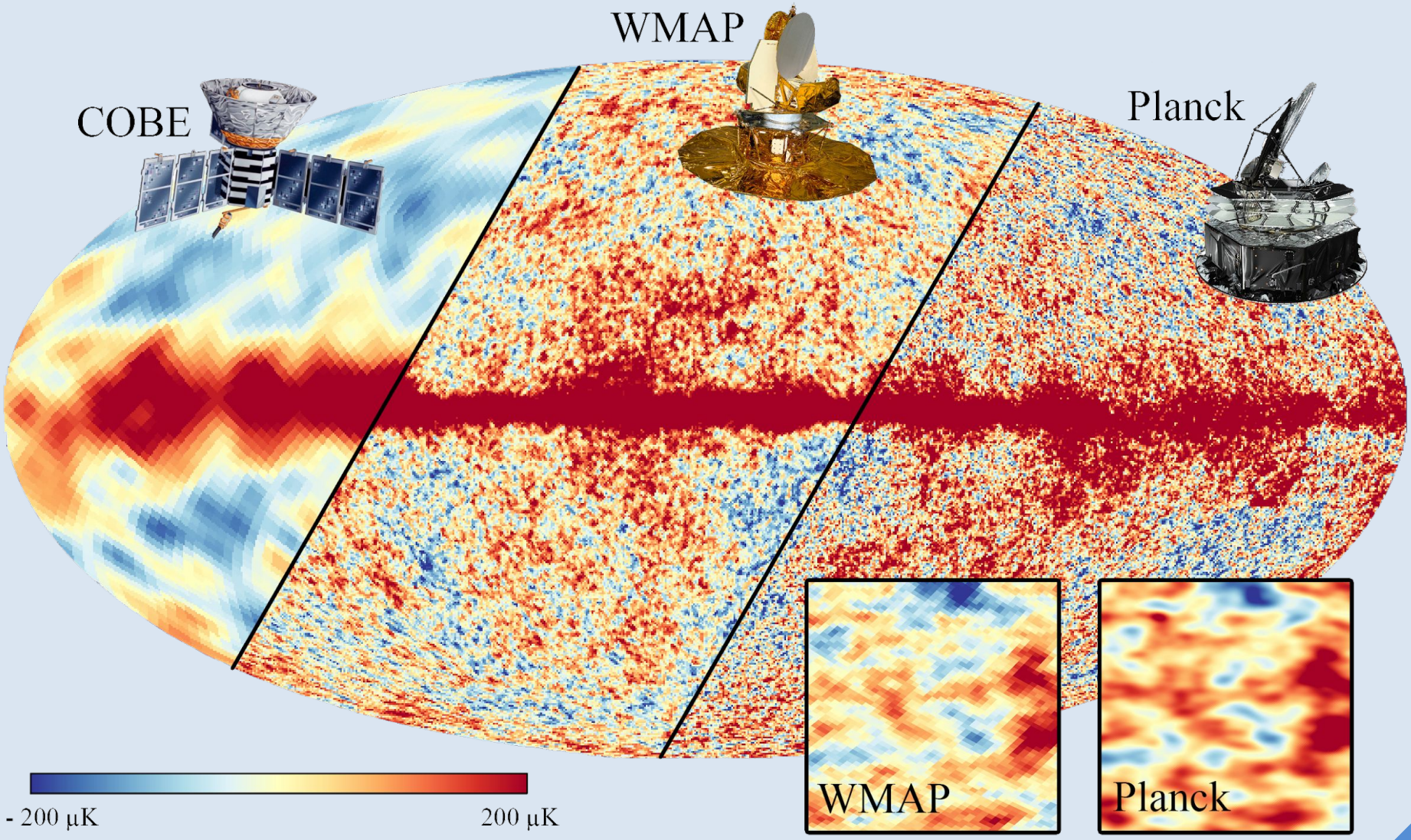
July 17, 2017

Jón E. Guðmundsson
The **Oskar Klein Centre** for Cosmoparticle Physics,
Stockholm University

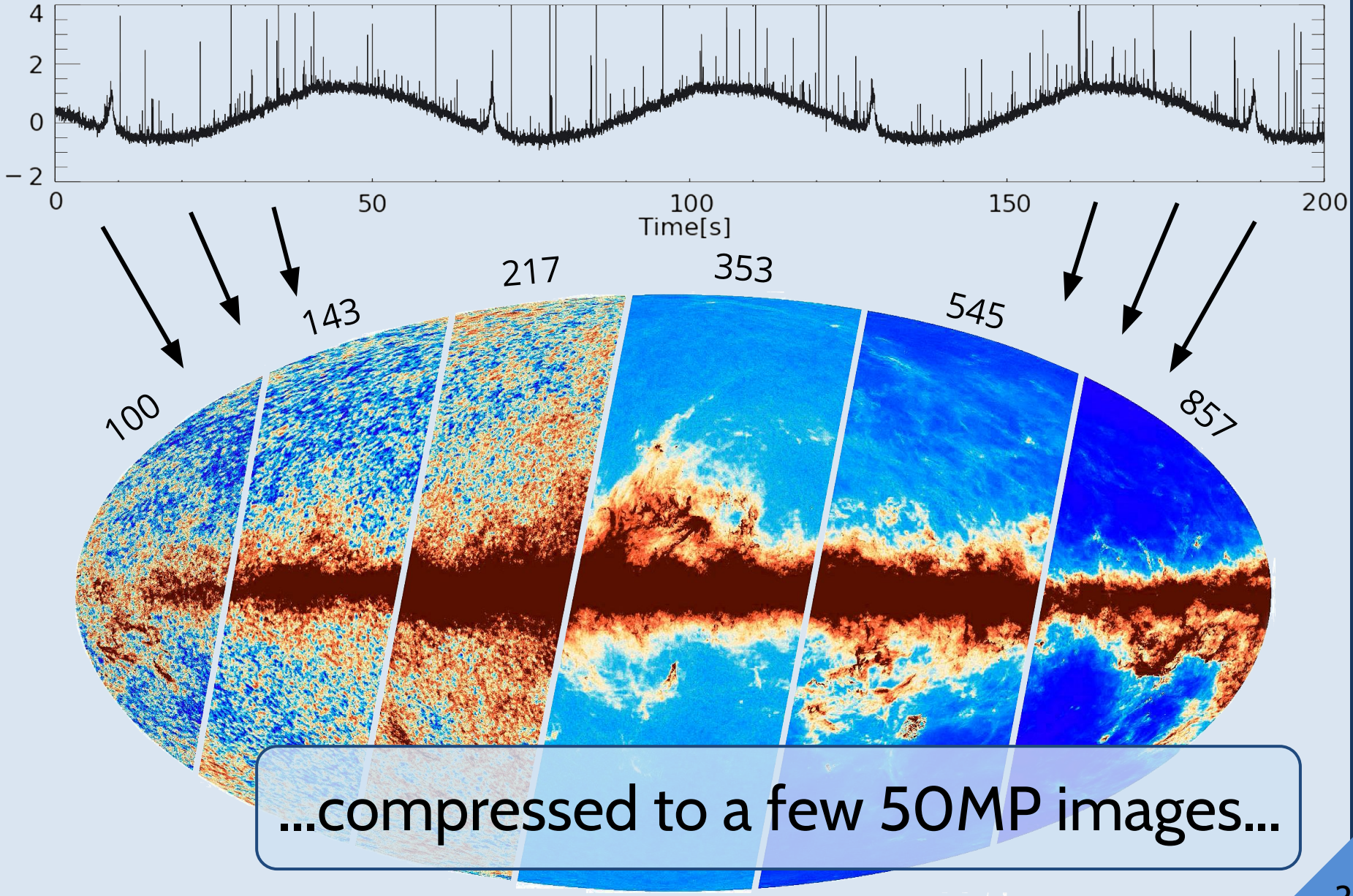
standing in for **William Jones**
Princeton University

on behalf of the SPIDER Collaboration

The Gold Standard

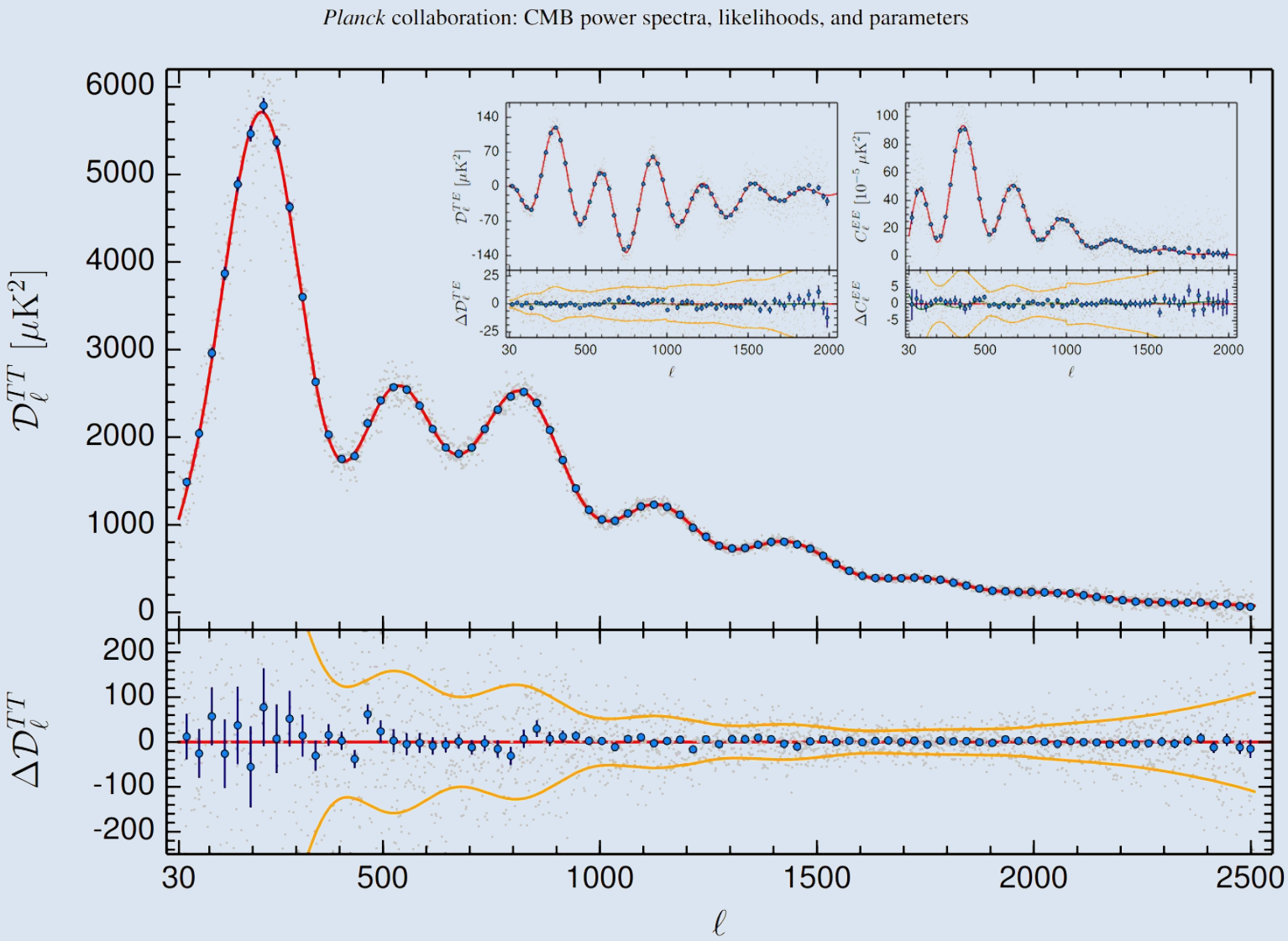


Terabytes of raw Planck data...



...compressed to a few 50MP images...

...reduced to about 10k coefficients (modes)...

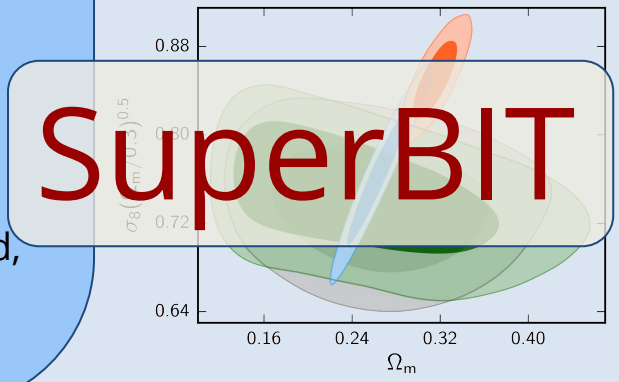


...to which 6 parameters are fit

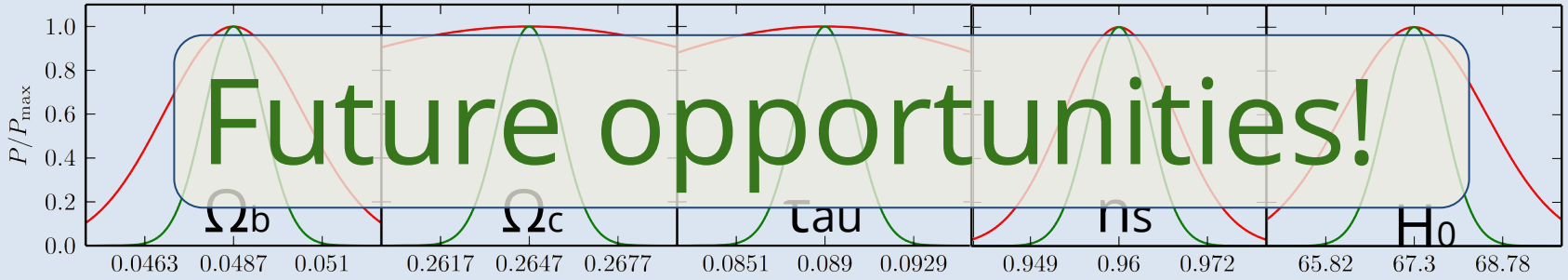
But there are caveats...

- Beyond LCDM — the early universe
  - Pay no attention to the man behind the curtains
  - **Mild** indication of departure from LCDM
  - Inflation vs alternatives
- Cosmological concordance
  - The amplitude of linear fluctuations as measured at low redshift (with galaxy clusters and cosmic shear) appears significantly lower than that predicted by ΛCDM + CMB
- Degeneracies with τ pose a limitation
  - The optical depth of reionization is not well constrained, and degeneracies with cosmological parameters and neutrino mass are large

National Geographic



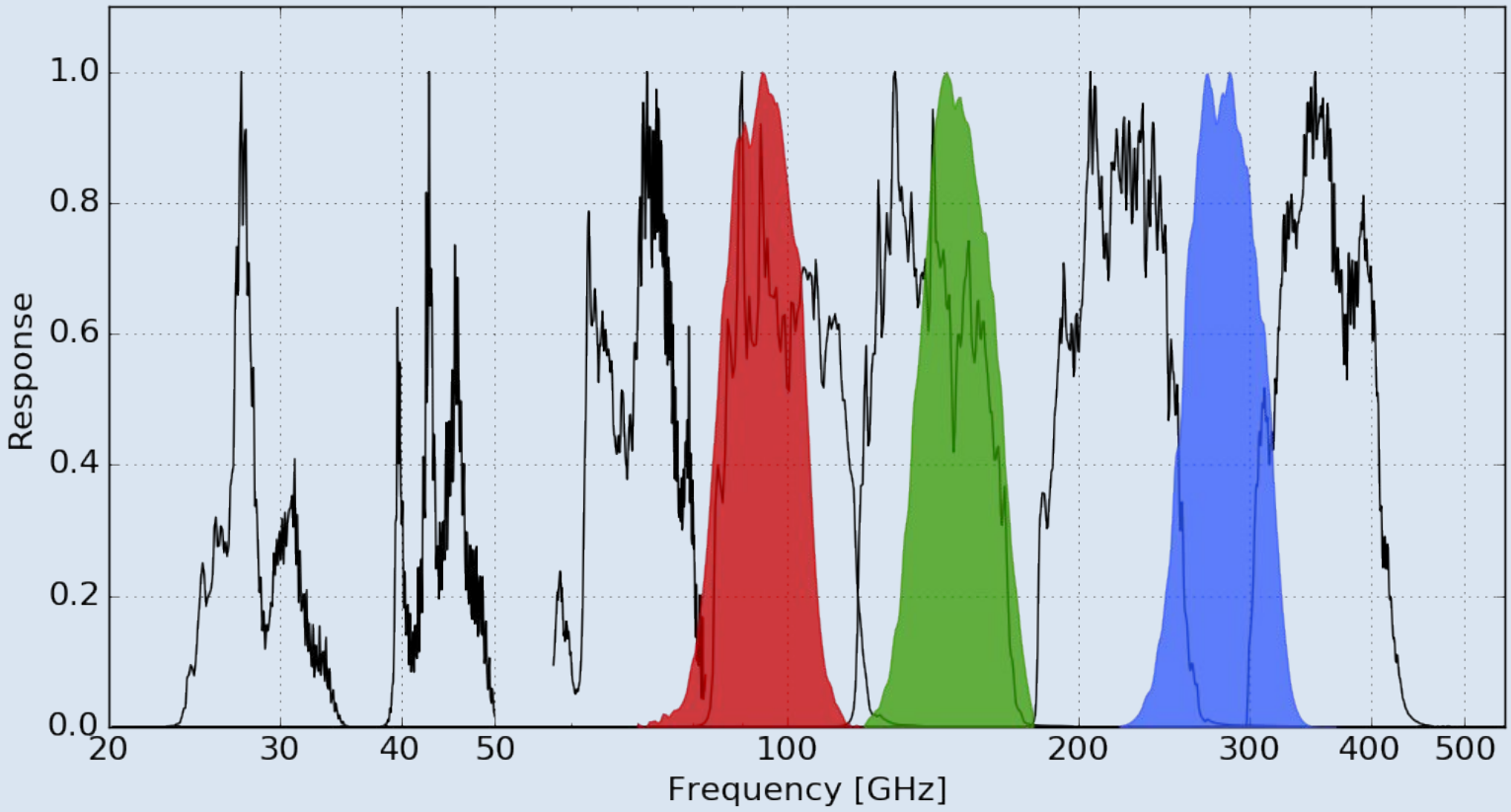
Hildebrandt et al. (2016)



The observational challenge

To clearly separate a primordial signal from more local sources we must

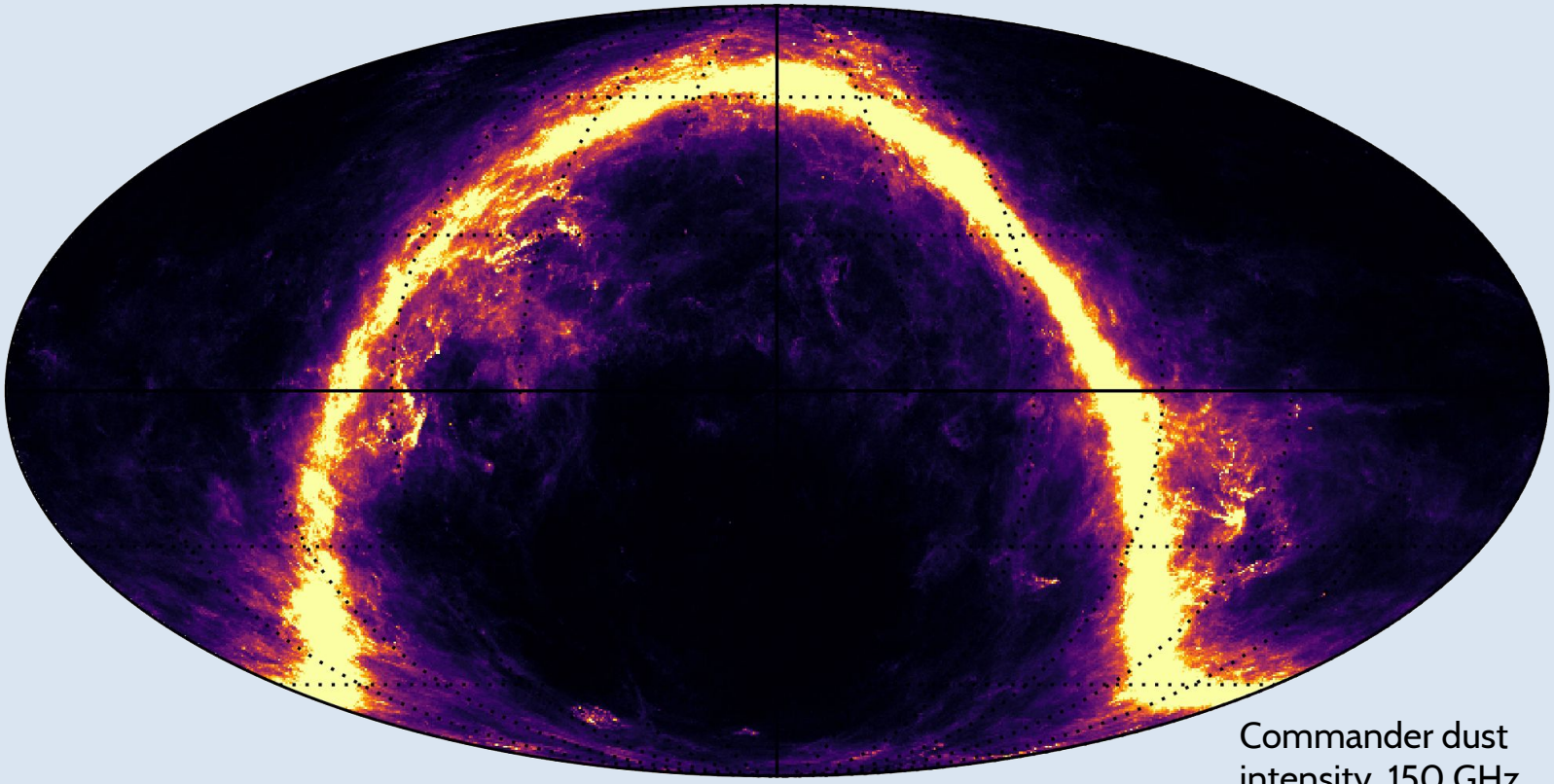
Constrain spectral energy distribution



The observational challenge

To clearly separate a primordial signal from more local sources we must

Constrain spectral energy distribution — **Verify statistical isotropy**

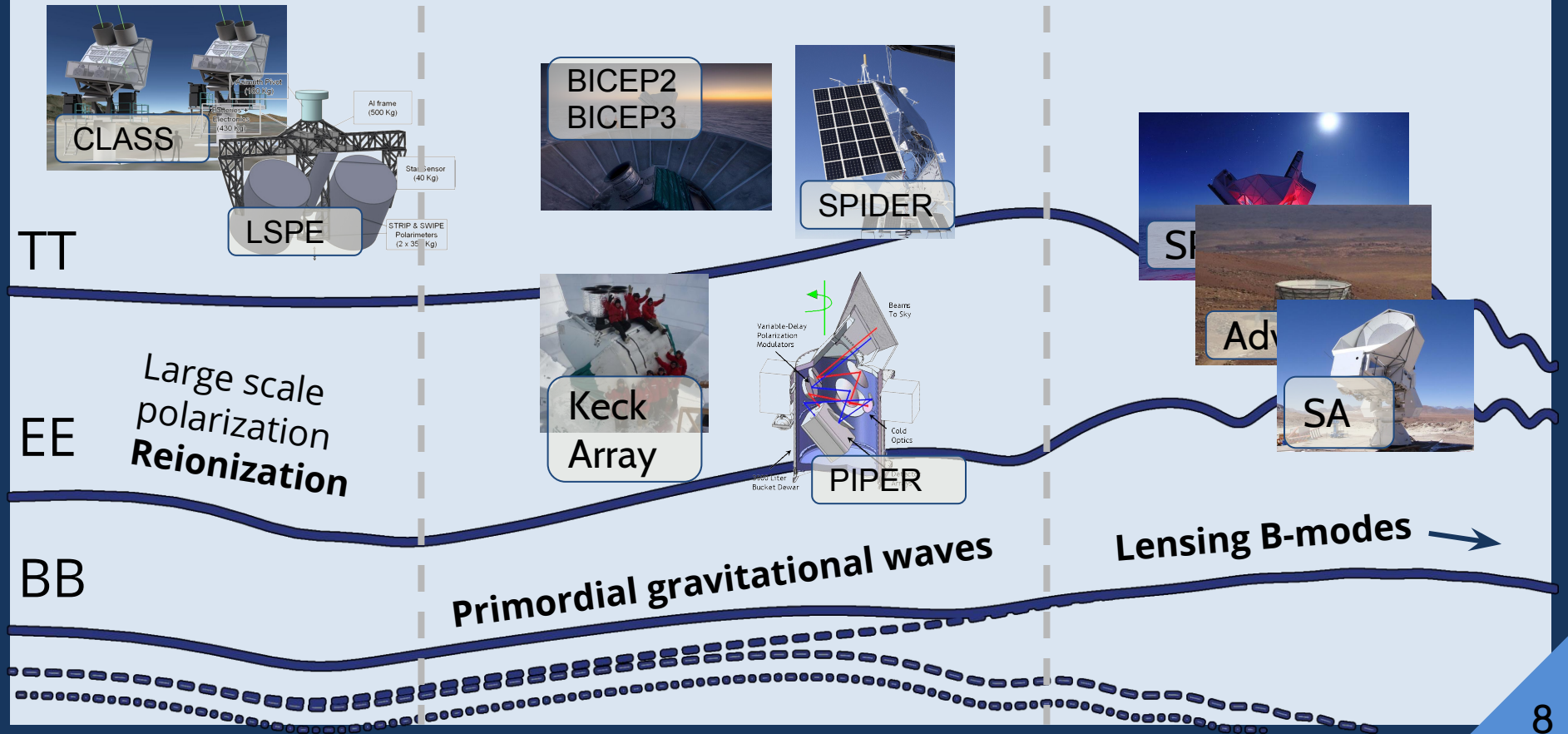


Commander dust intensity, 150 GHz

The observational challenge

To clearly separate a primordial signal from more local sources we must

Constrain spectral energy distribution — Verify statistical isotropy — **Probe all angular scales**



December 2014
ca. Ross Island, Antarctica

NASA CSA ASC JPL NIST CITA ICAT CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD UBC CASE WESTERN RESERVE UNIVERSITY since 1826 PRINCETON UNIVERSITY UNIVERSITY OF TORONTO Imperial College London KICC UNIVERSITY OF KWAZULU-NATAL INYUVESI YAKWAZULU-NATALI ILLINOIS IAS Stockholm University ASU

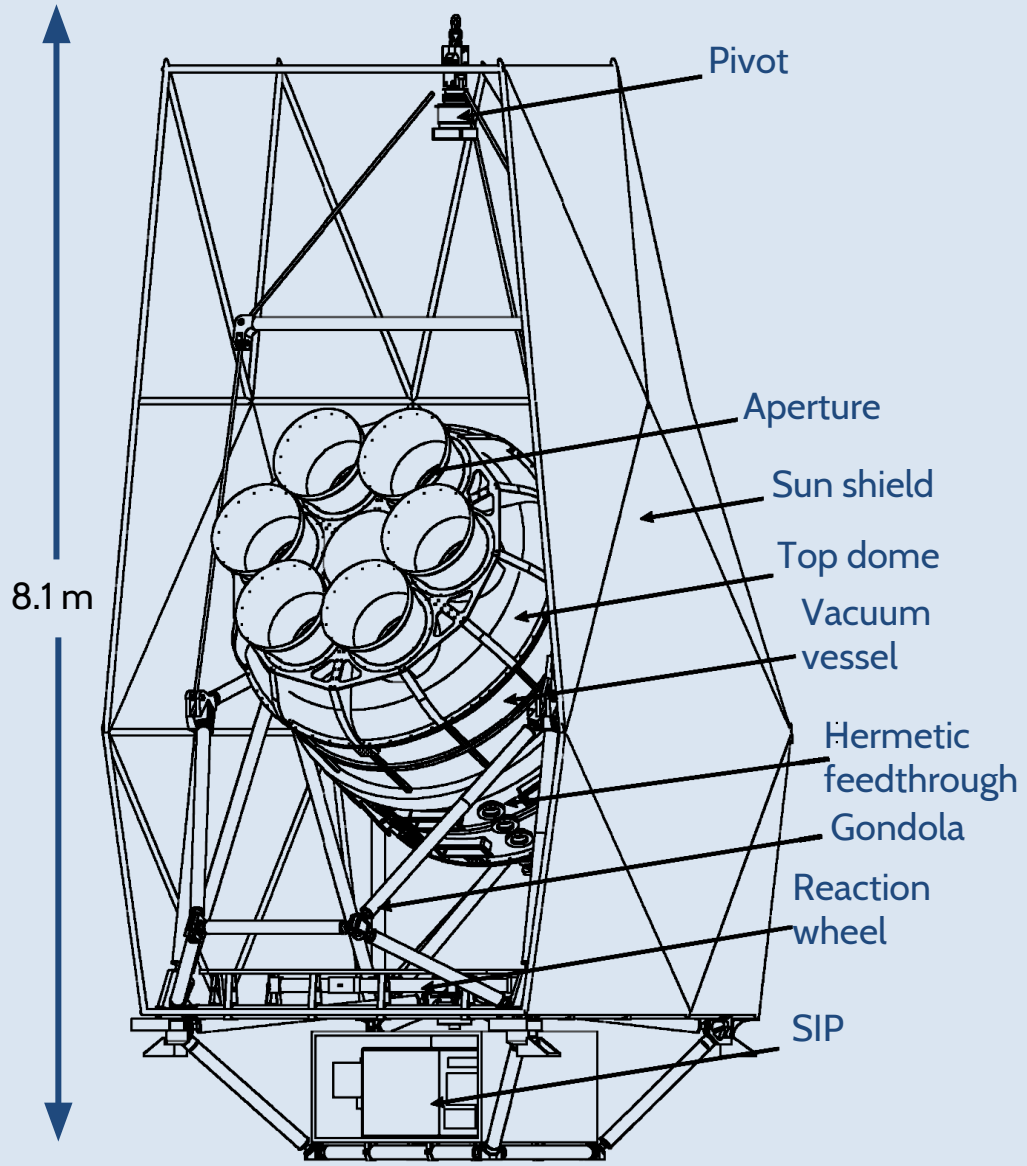
Primary characteristics

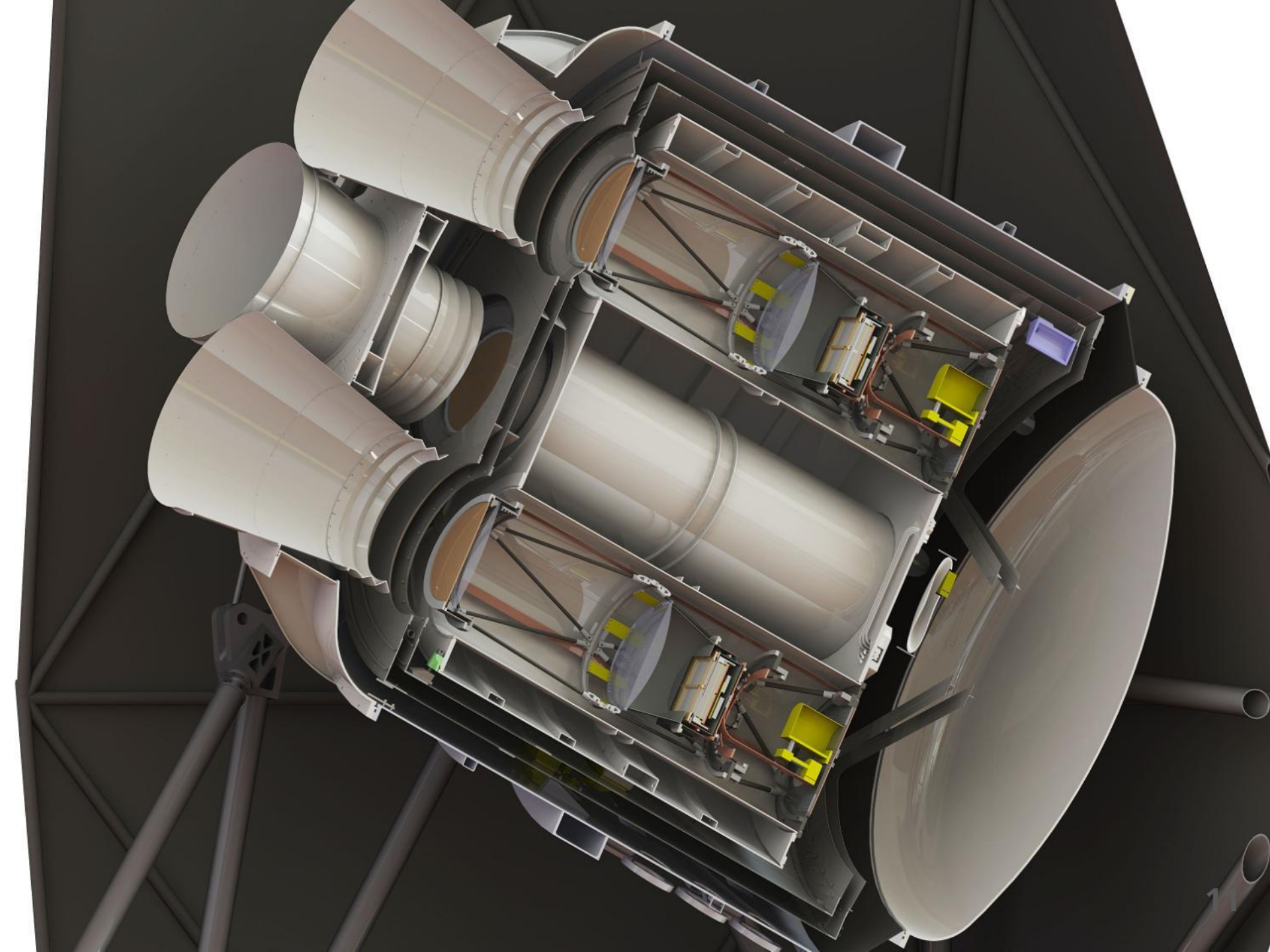
Sky coverage	About 10 %
Scan rate (az)	3.6 deg/s at peak
Polarization modulation	Stepped cryogenic HWP
Detector type	Antenna-coupled TES
Multipole range	$10 < \ell < 300$
Observation time	16 days at 36 km
Limits on $r^{\dagger}$	0.03

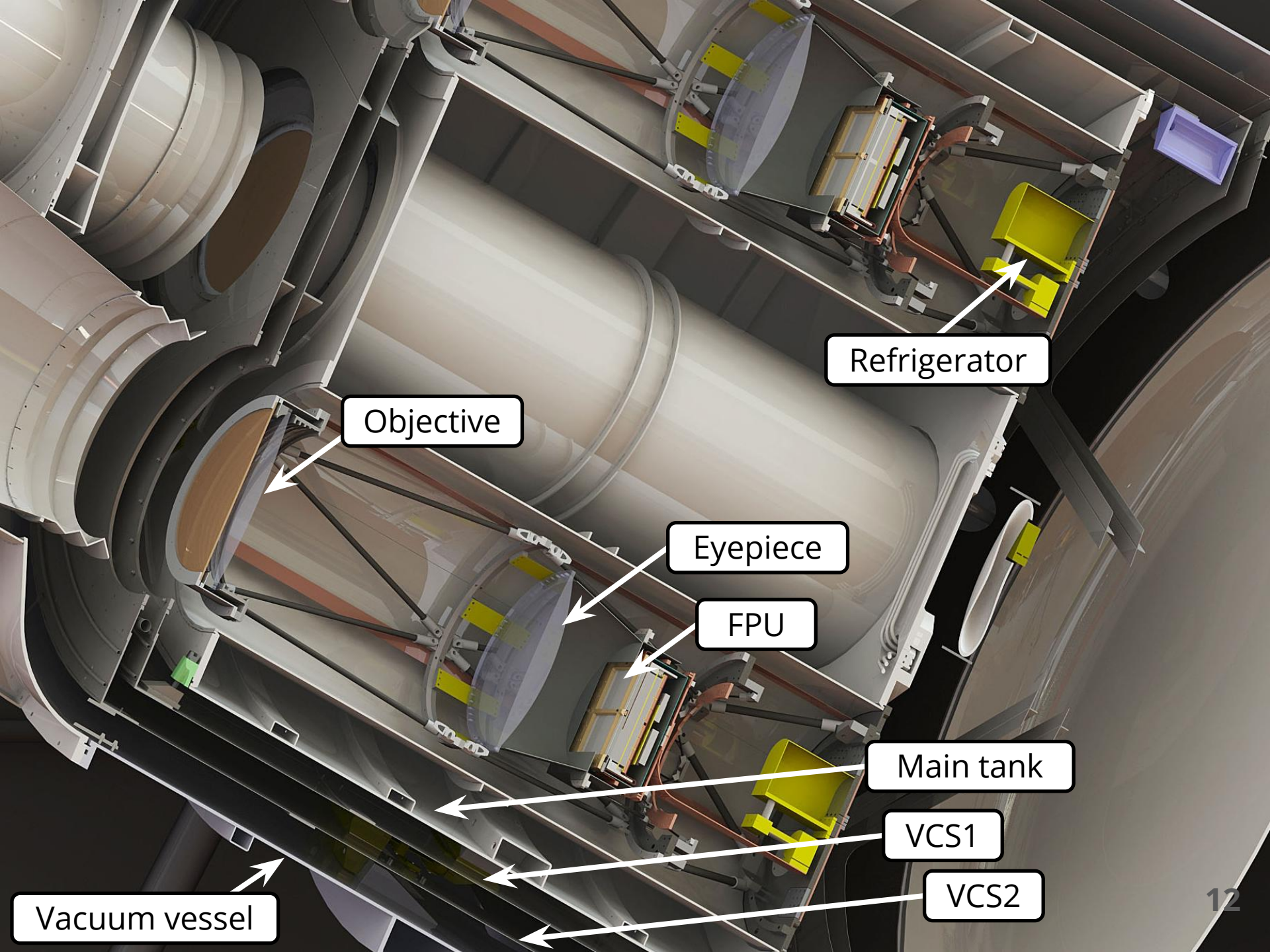
† Assuming no foregrounds, at 99% confidence

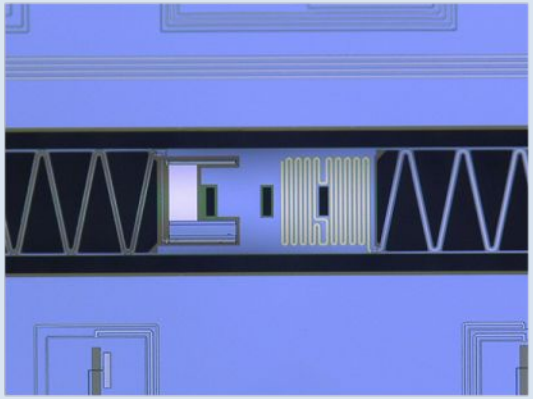
	Frequency [GHz]	
	95	**150**
Telescopes	3	3
Bandwidth [GHz]	22	36
Optical efficiency	30-45%	30-50%
Angular resolution* [arcmin]	41.1	28.2
Number of detectors†	675	1188
Detector loading‡ [pW]	≤ 0.25	≤ 0.35
Instrument NET [μK·rts]	7.1	5.3

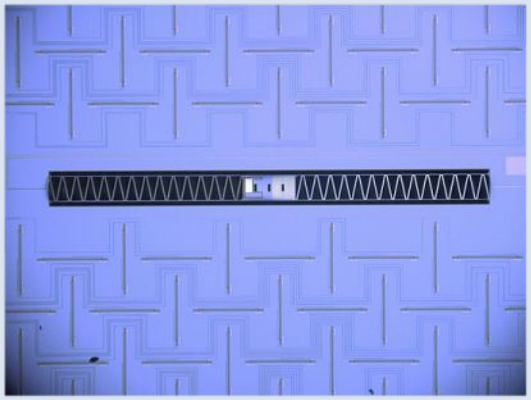
*FWHM. †Current channel cuts
‡Including atmosphere, sleeve, window, and baffle

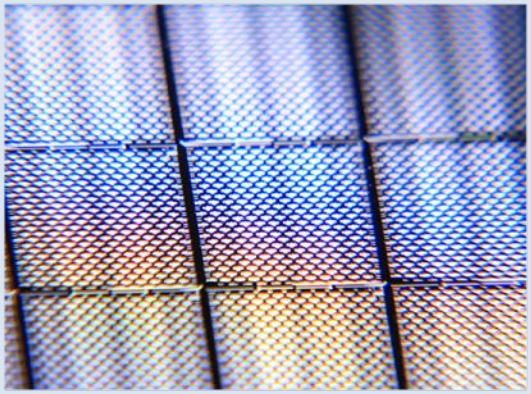


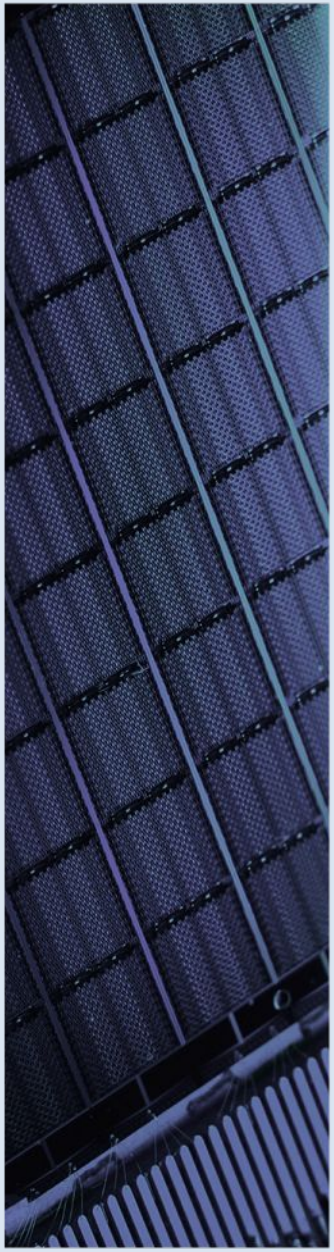


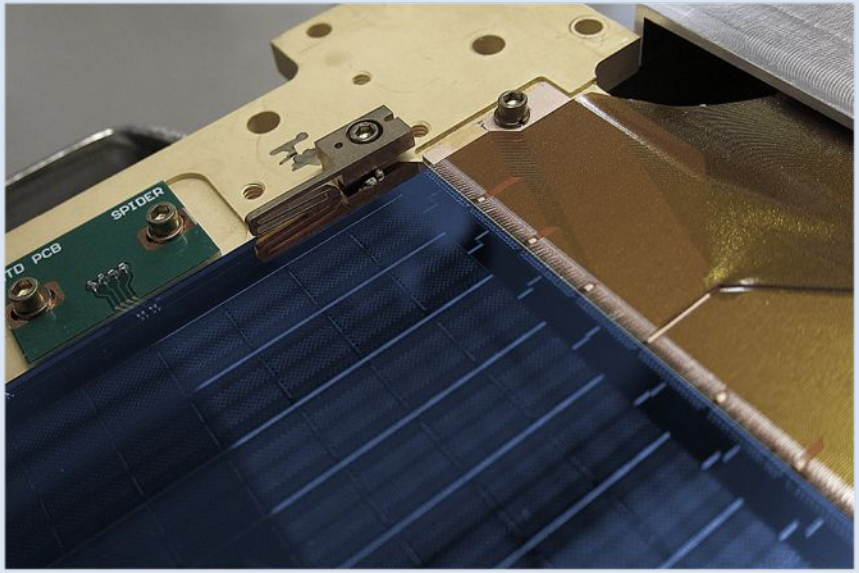

Refrigerator
Objective
Eyepiece
FPU
Main tank
VCS1
VCS2
Vacuum vessel

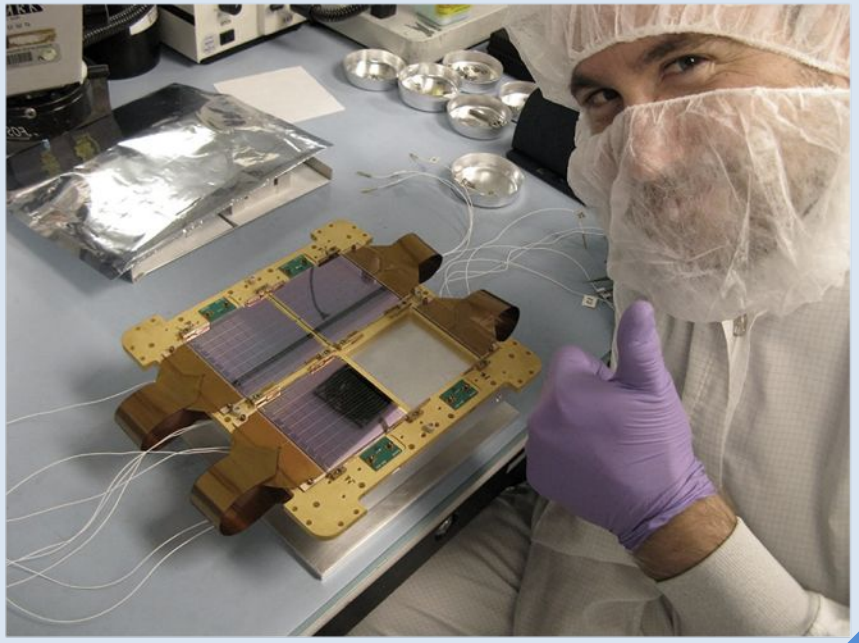








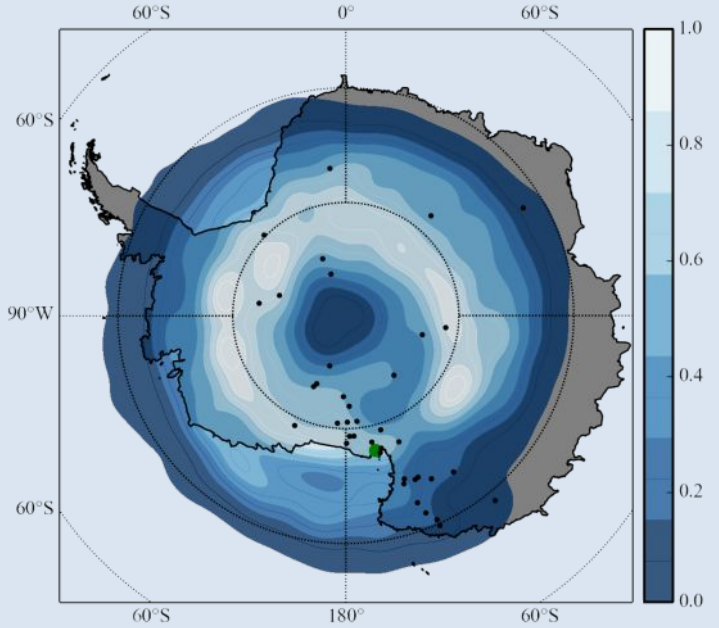




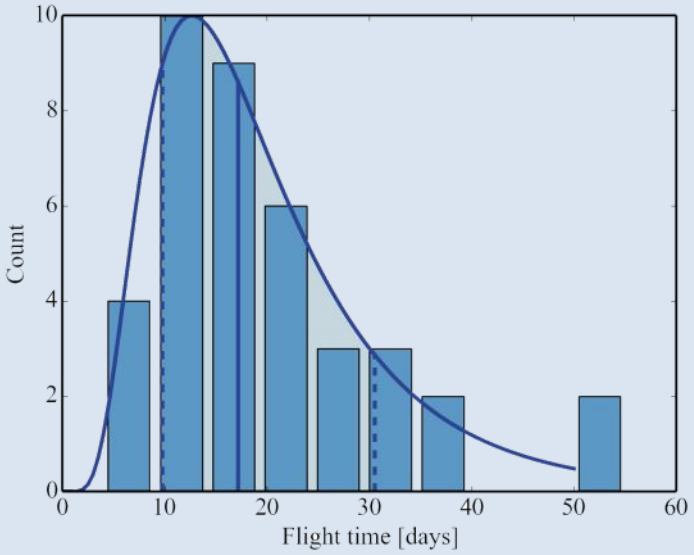
JPL Microdevices Lab

Long Duration Ballooning

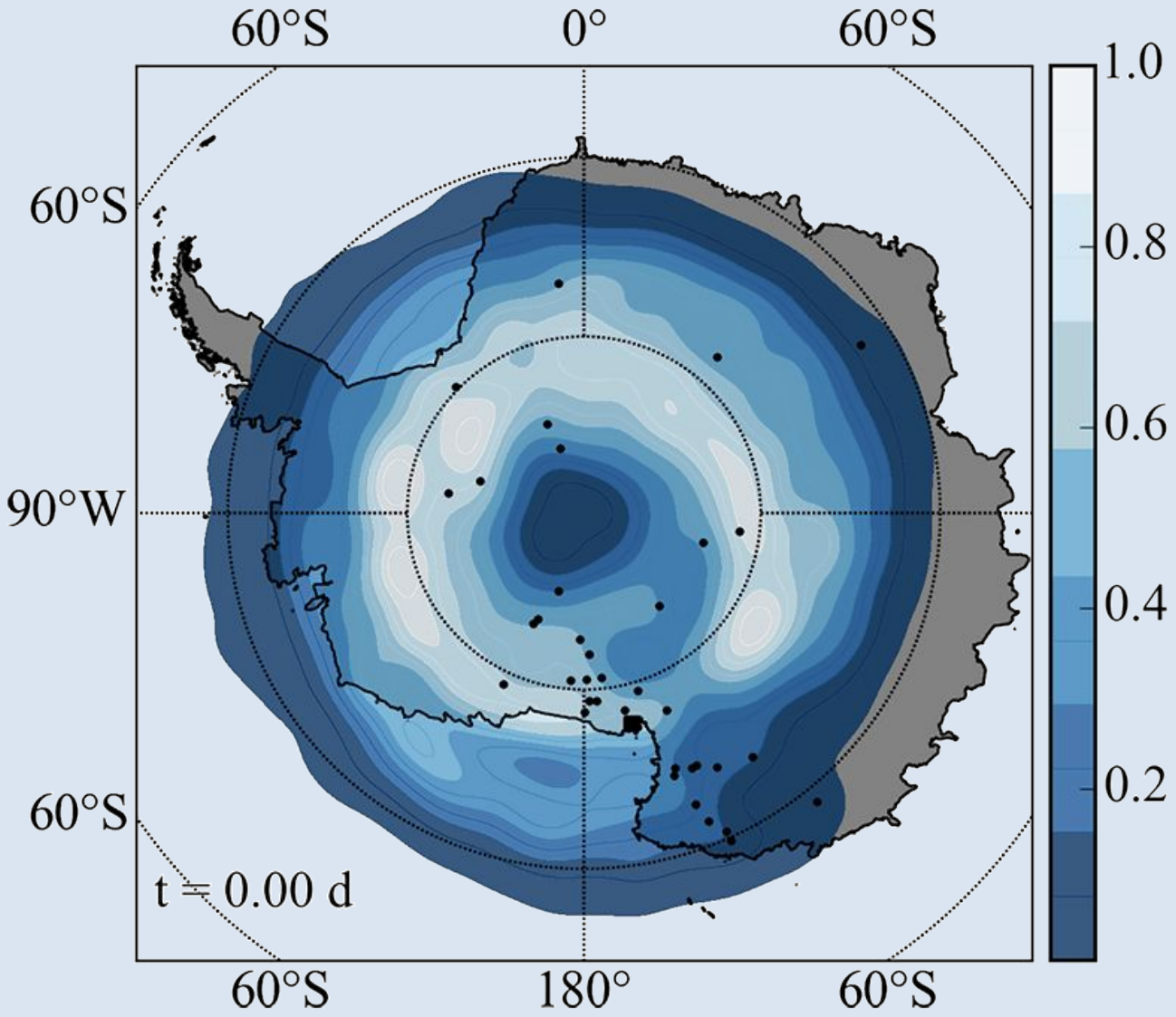
- Circumpolar winds ~10 days/rev
- On average 20 day flights at 36 km
- **Why Ballooning?**
- Space like loading (NET)
- Access to larger angular scales
- Wider frequency windows
- Preparation for SPB promised land
- **Why Antarctica?**
- Continuous solar power
- Long flight times
- **At what price?**
- Narrow launch windows
- Recovery difficulties
- Mass, power, and automation



Data from CSBF



Our trajectory



Feb 5, 2015 — data recovery

Fig. BAS

Nov 17, 2015 — payload recovery

Fig. Ed Young

Oct 13, 2016 — recycled aluminum

Observation regions

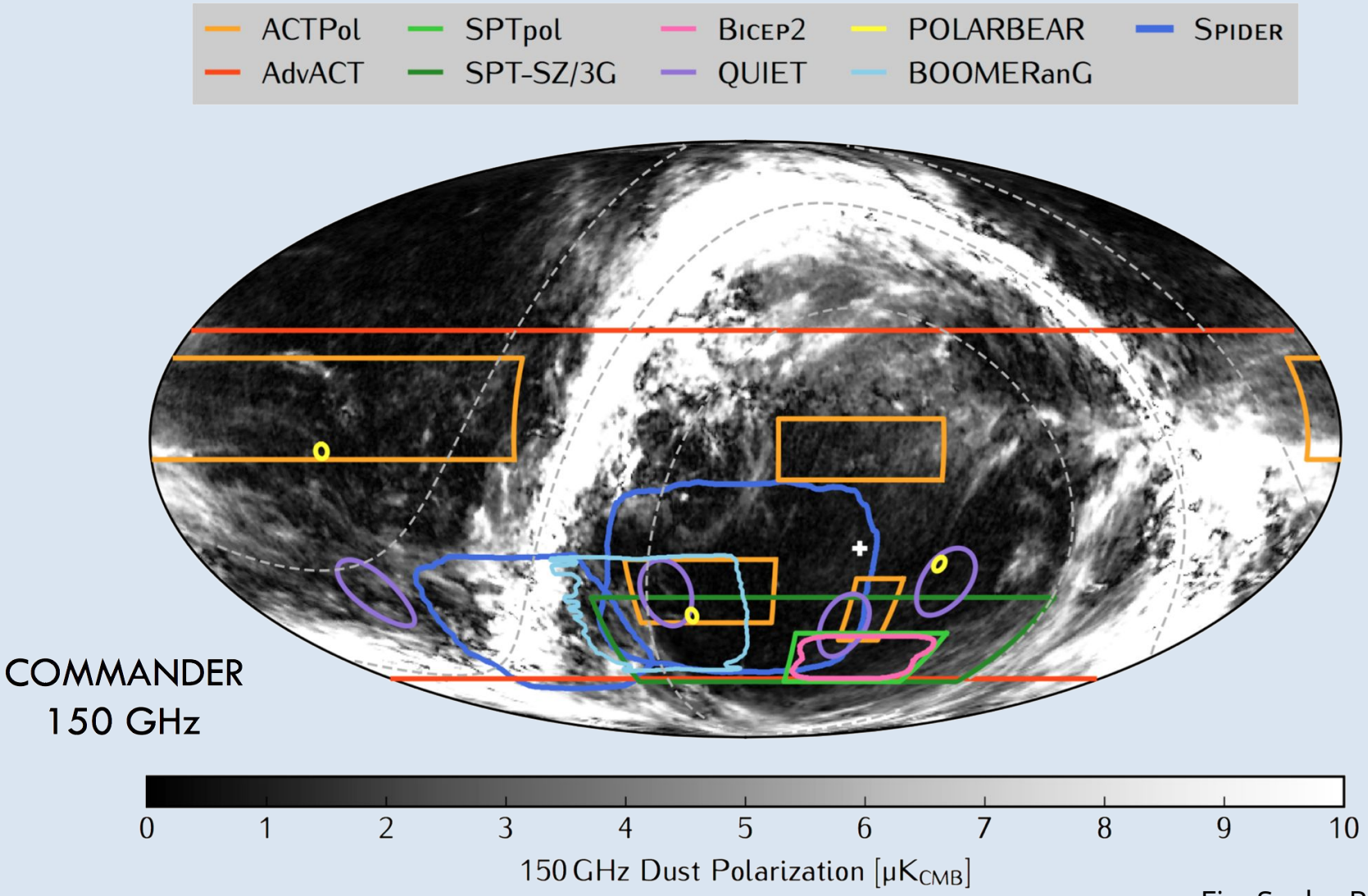


Fig. Sasha Rahlin

Polarization amplitude

- SPIDER scanned approximately 10% of the sky

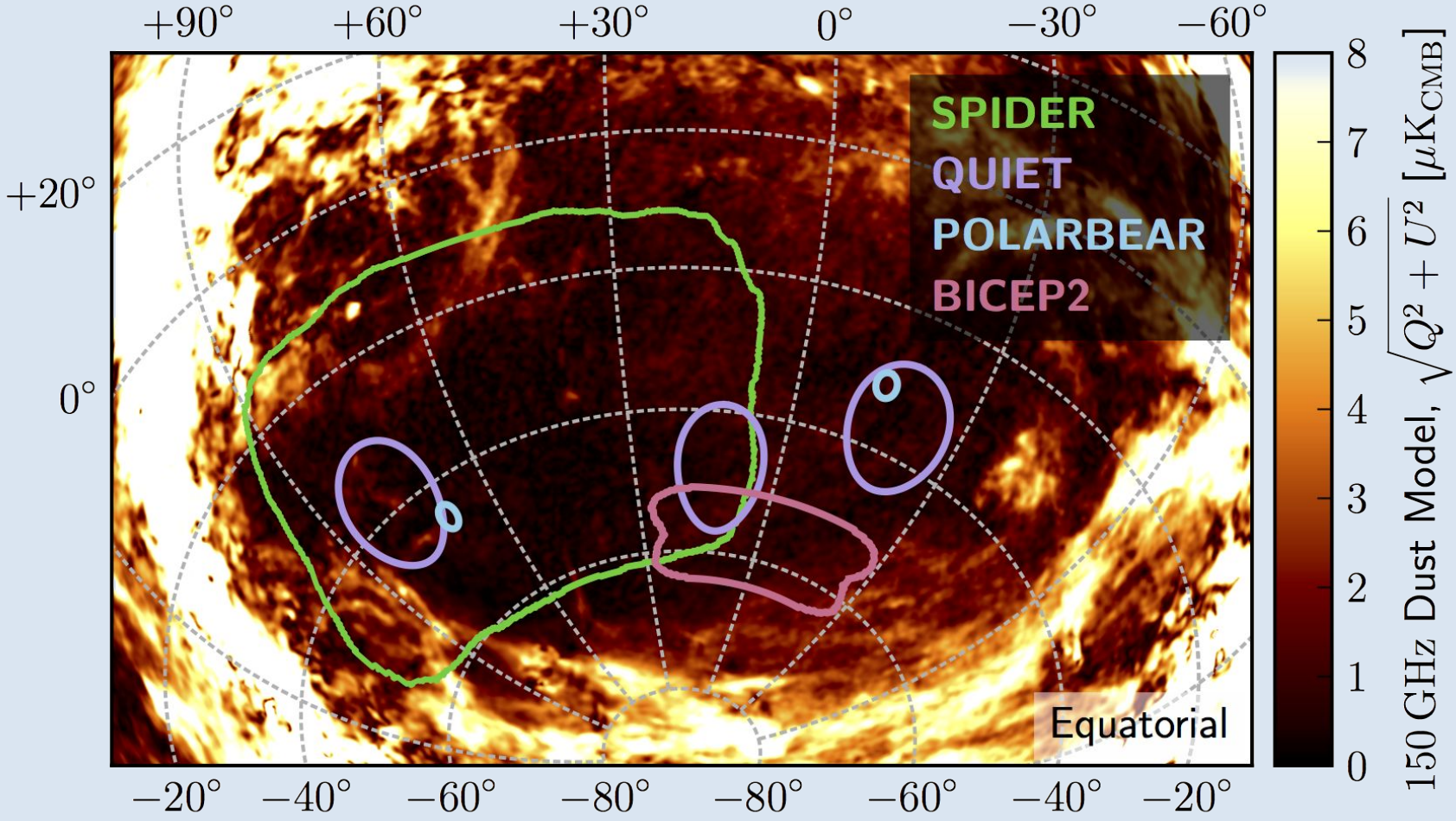
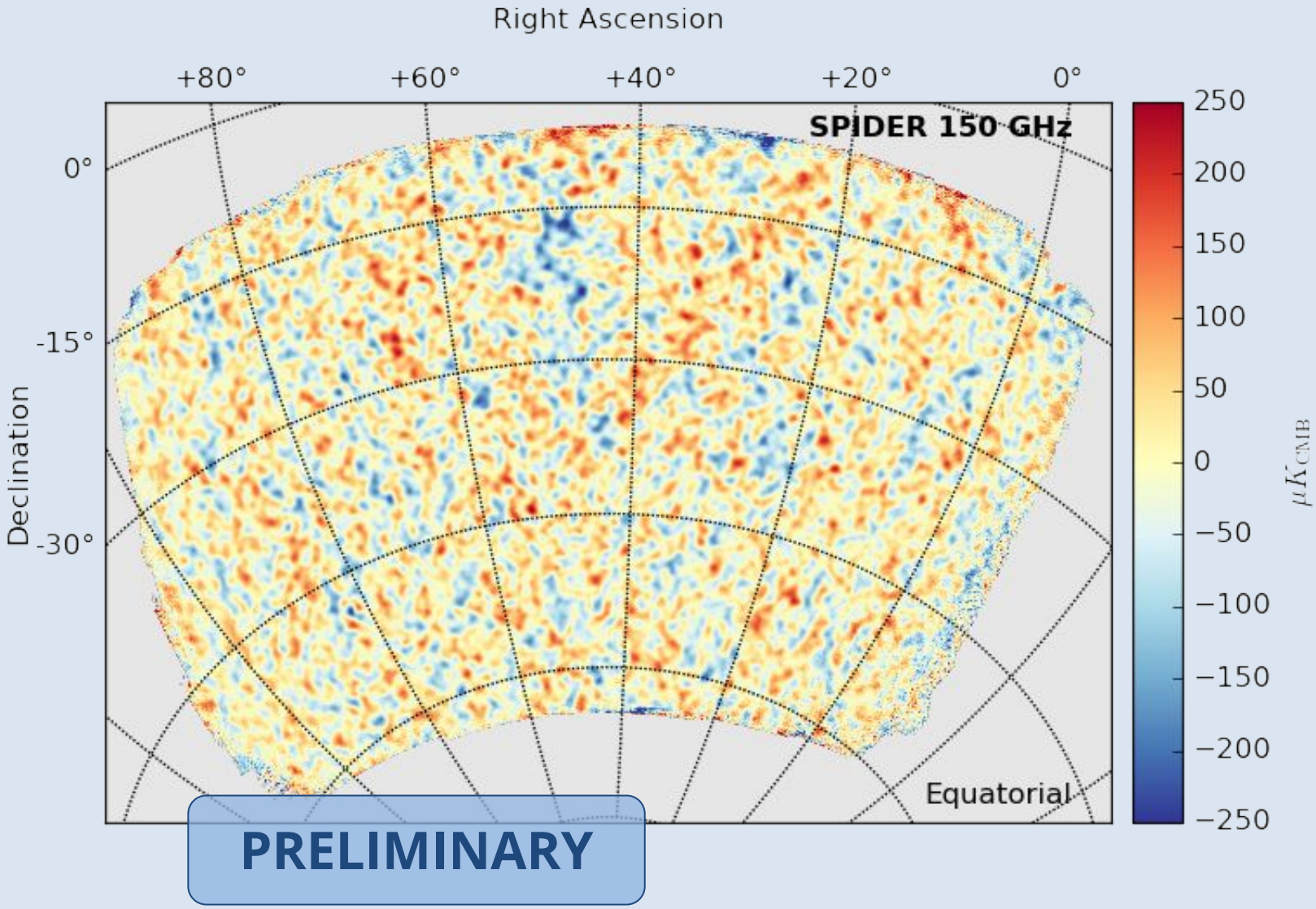
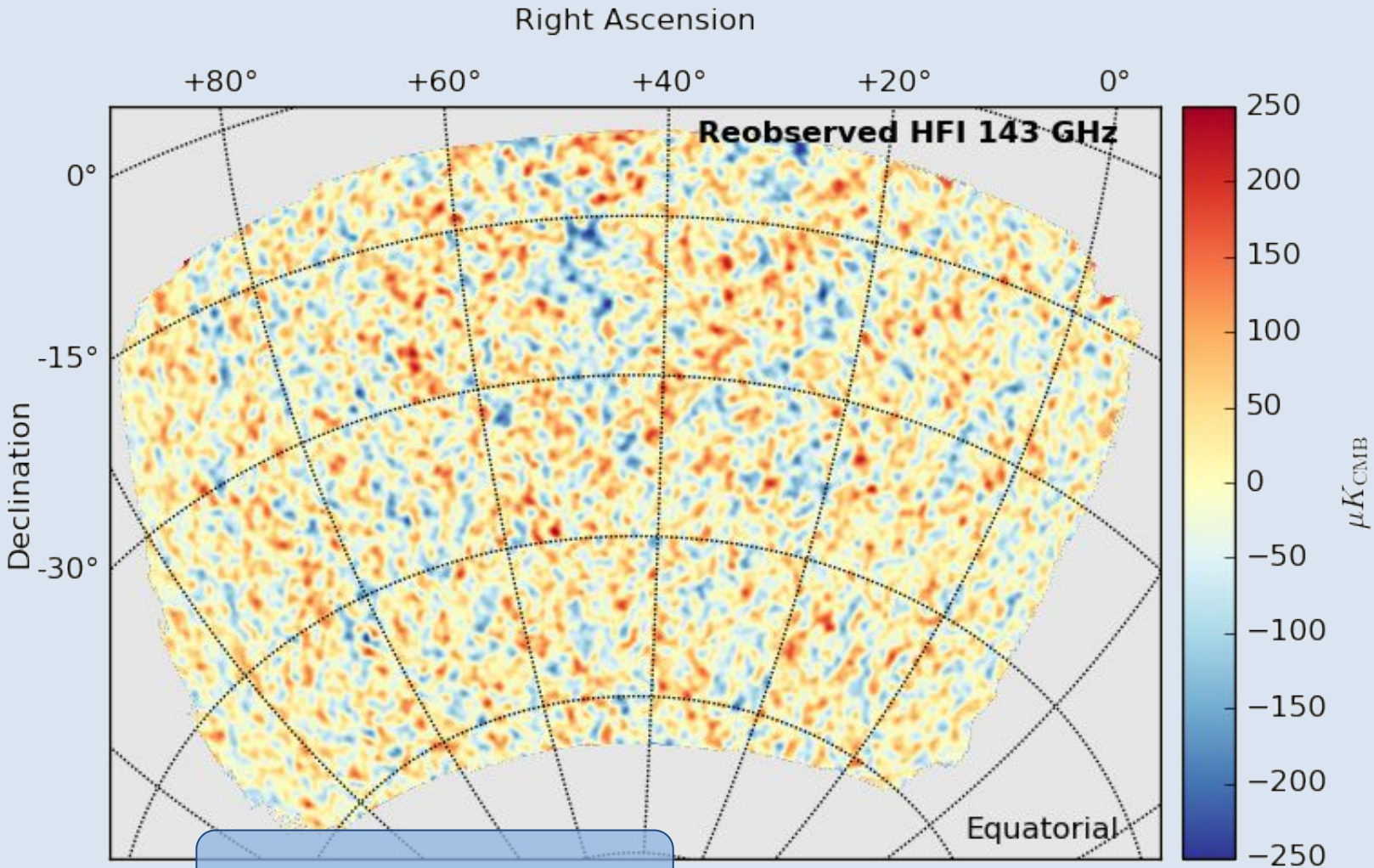


Fig. Sasha Rahlin

SPIDER 150 GHz band : Temperature



Comparison to *Planck* HFI : Temperature



Planck PR2 Maps, nominal Full Misison map

Stacking hot spots : SPIDER

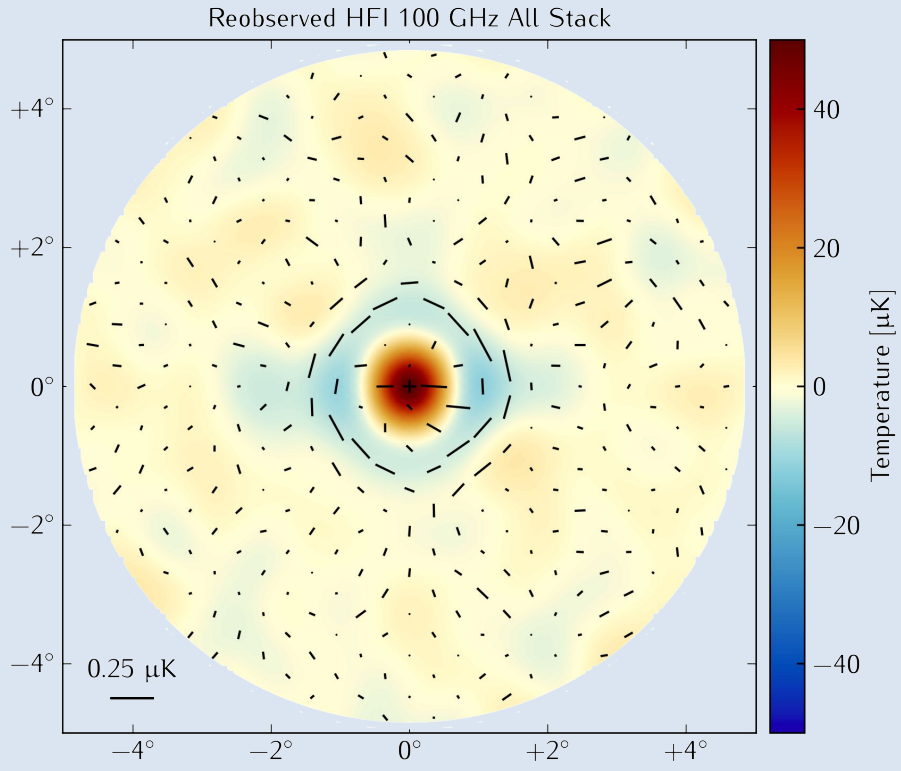
Figure removed from online version.

PRELIMINARY

PRELIMINARY

Fig. Sasha Rahlin

Stacking hot spots : Planck



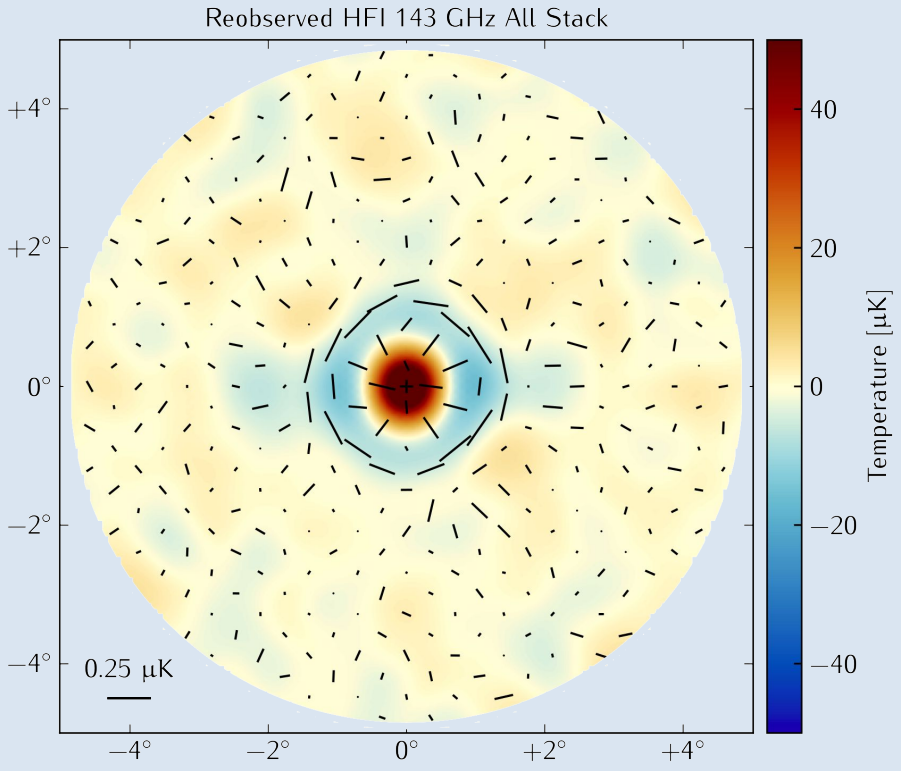


Fig. Sasha Rahlin

SPIDER : full flight I**QU**

Figure removed from online version.

PRELIMINARY

Fig. Sasha Rahlin

SPIDER – Planck : full flight I**QU**

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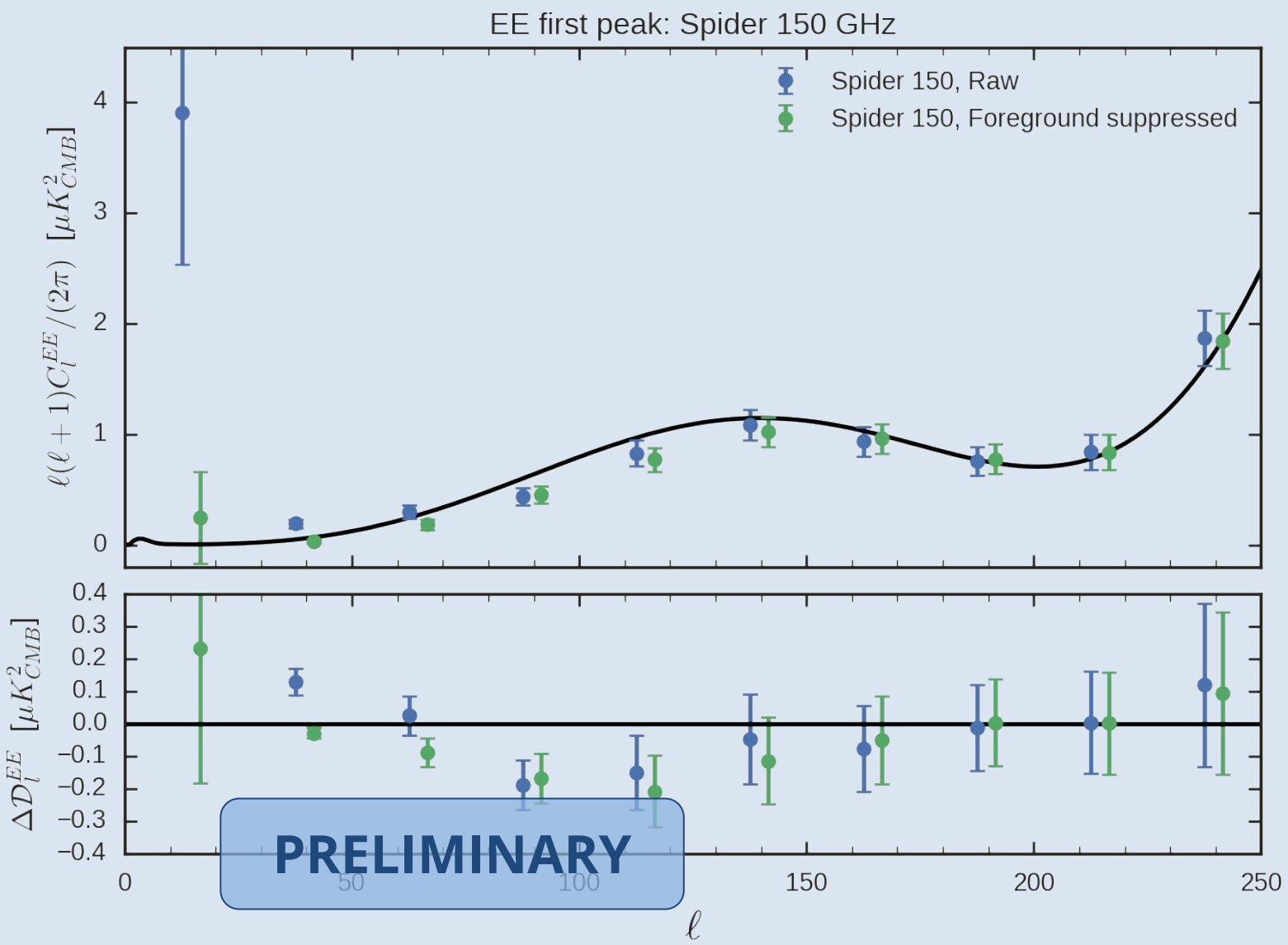
PRELIMINARY

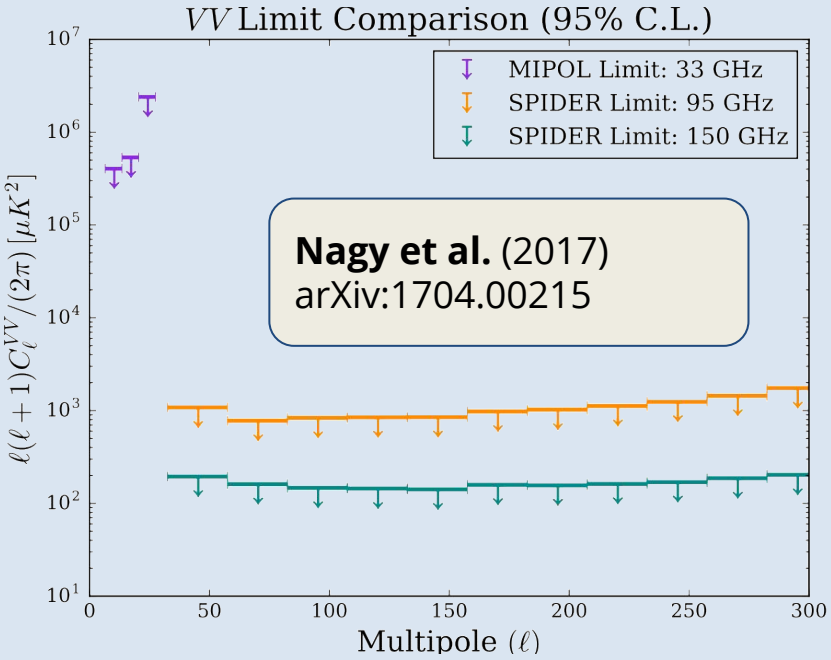
Fig. Sasha Rahlin

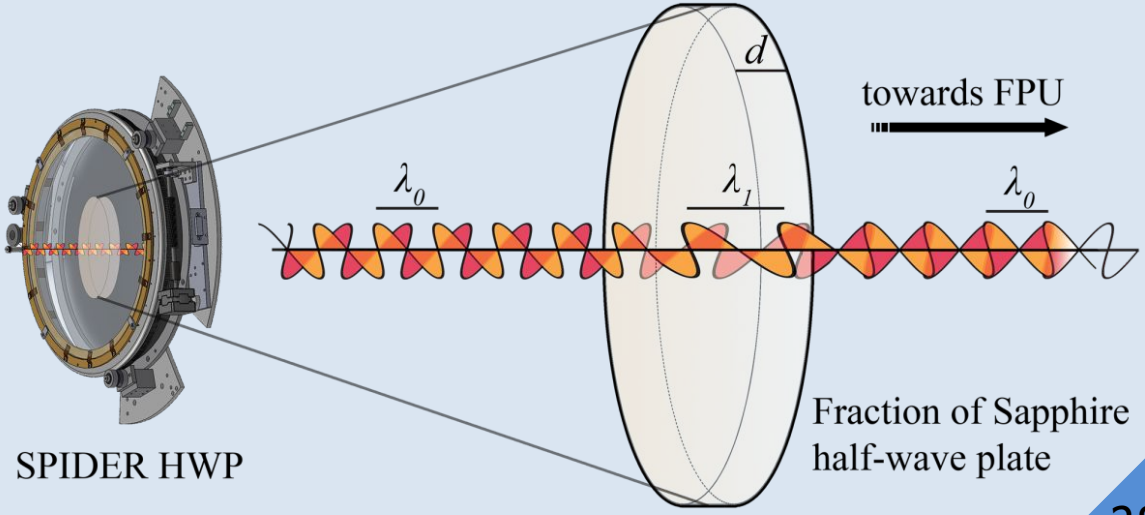
We detect polarized foregrounds



Recent limits on circular polarization

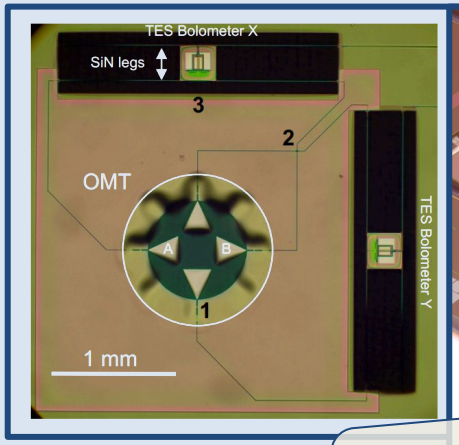
- Possible astrophysical V-pol production mechanisms:
  - Stellar remnant, galaxy cluster, and primordial magnetic fields, QED extensions, and so forth…
- Non-ideal half wave-plate partially transforms circular polarization to linear
  - Careful instrument characterization allows us to constrain circular polarization
- SPIDER improves limits by orders of magnitude

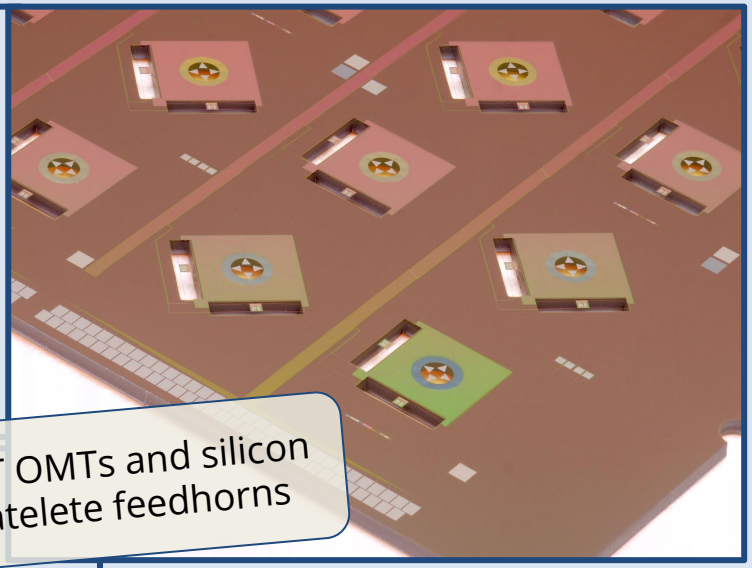




SPIDER-2 development

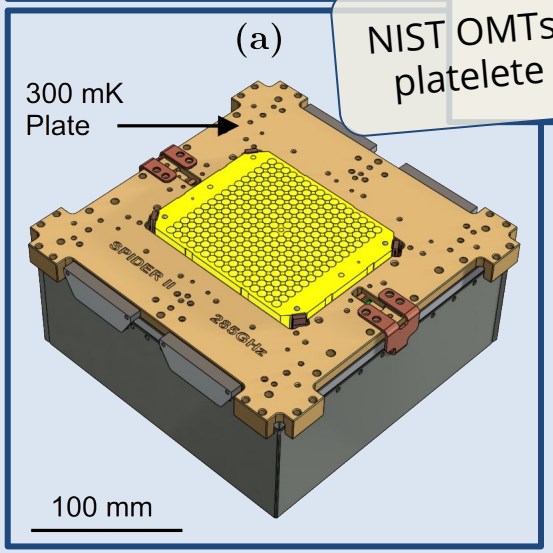
- Receivers operating at 285 GHz are built and undergoing testing
- Project about 335 uKrts sensitivity per detector and 17 arcmin beam

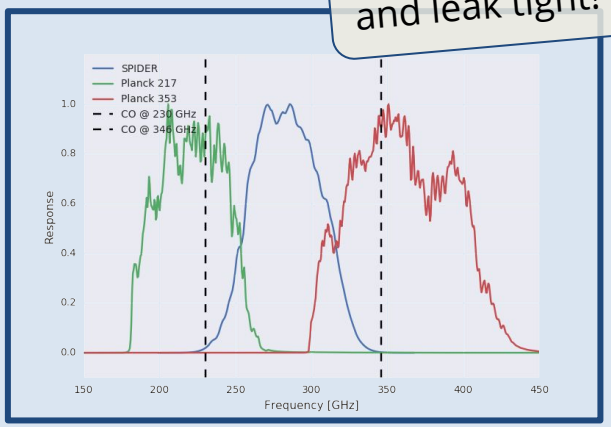




NIST OMTs and silicon platelete feedhorns

New cryostat built and leak tight!

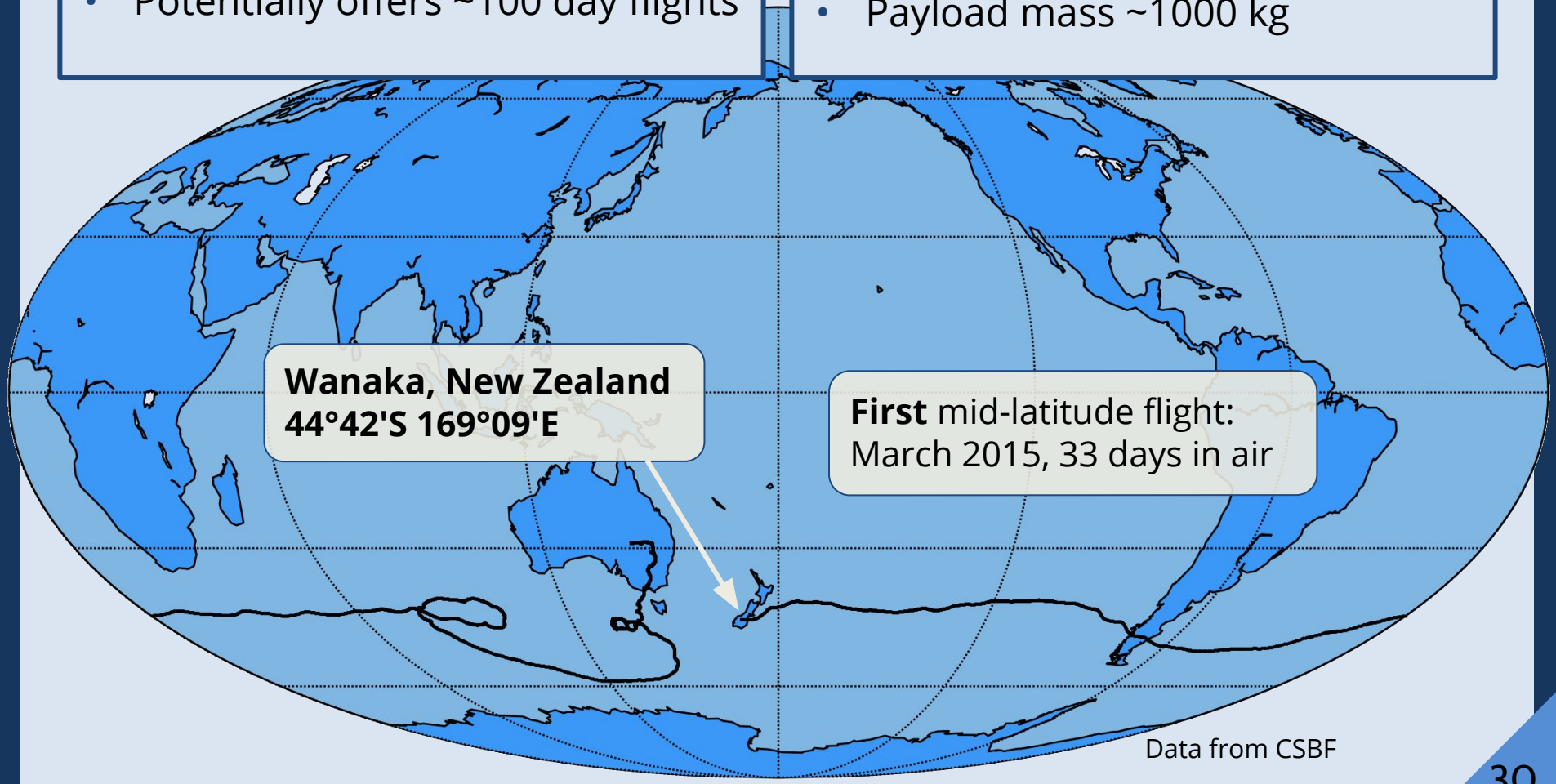




SPB Ballooning

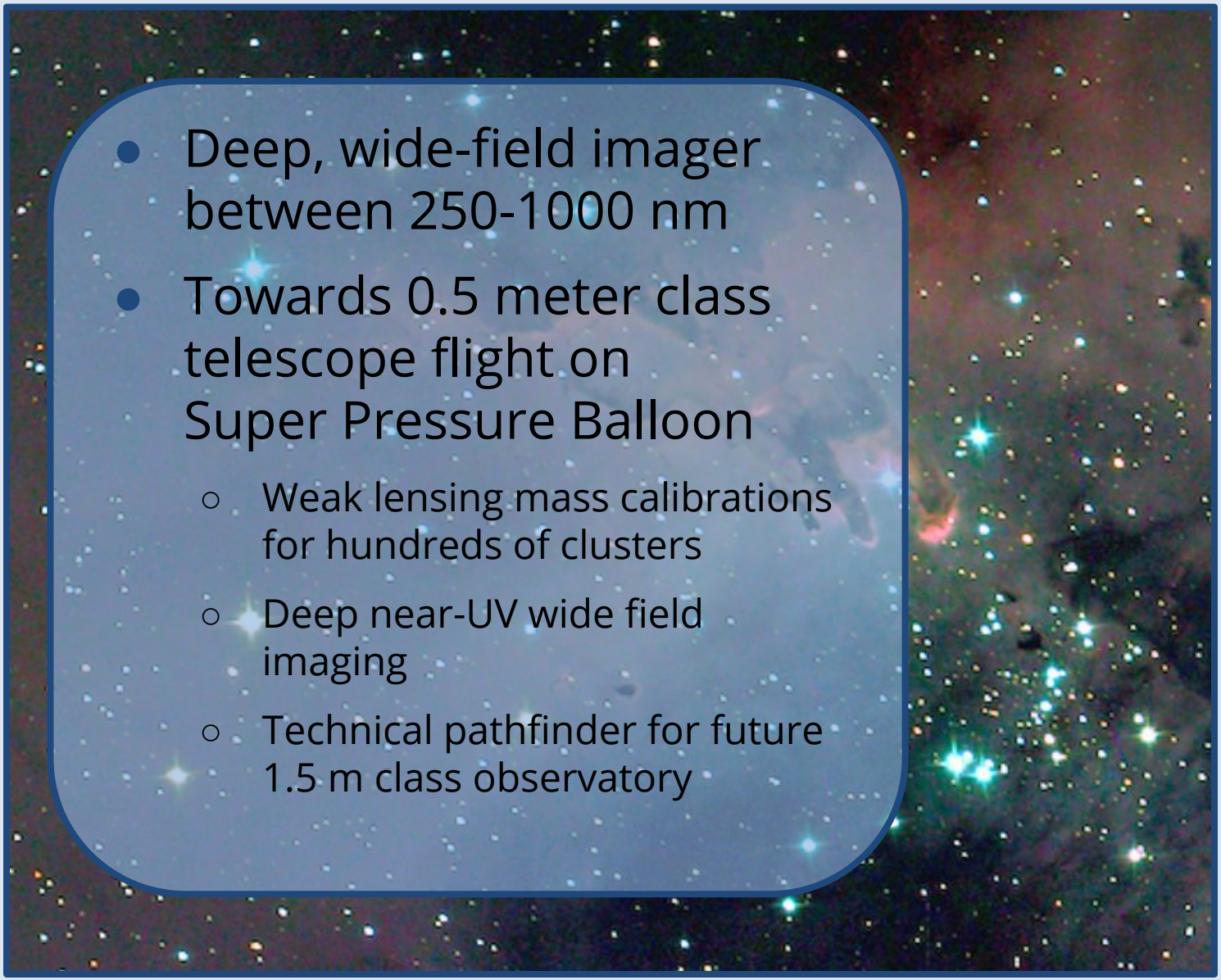
- Constant volume balloons
  - Stable altitude
- First science flight in 2016
- Potentially offers ~100 day flights

- Launch base in New-Zealand
- Intermediate latitudes
- Full diurnal cycles
- Payload mass ~1000 kg



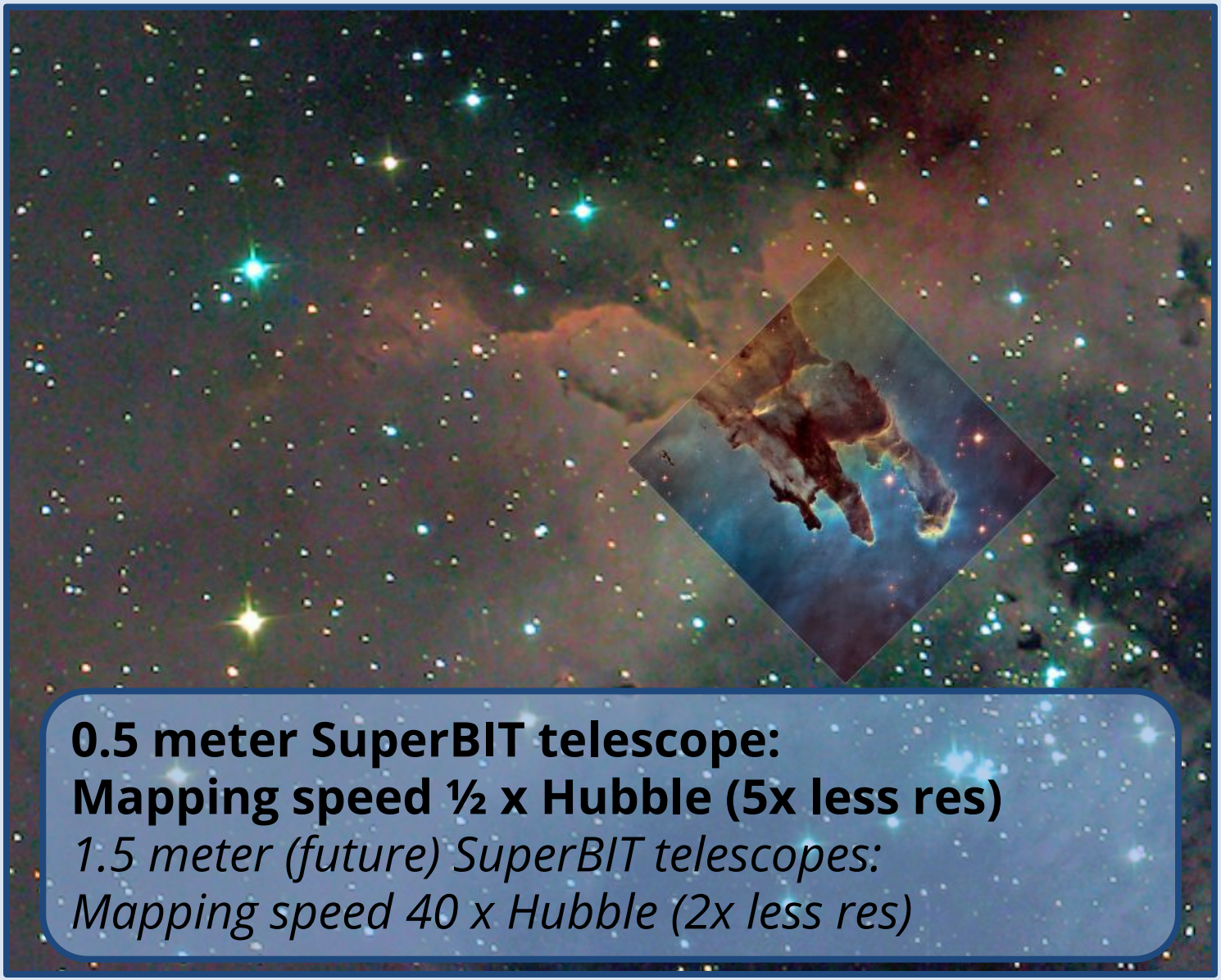
Data from CSBF

SuperBIT Palestine 2016 Test Flight



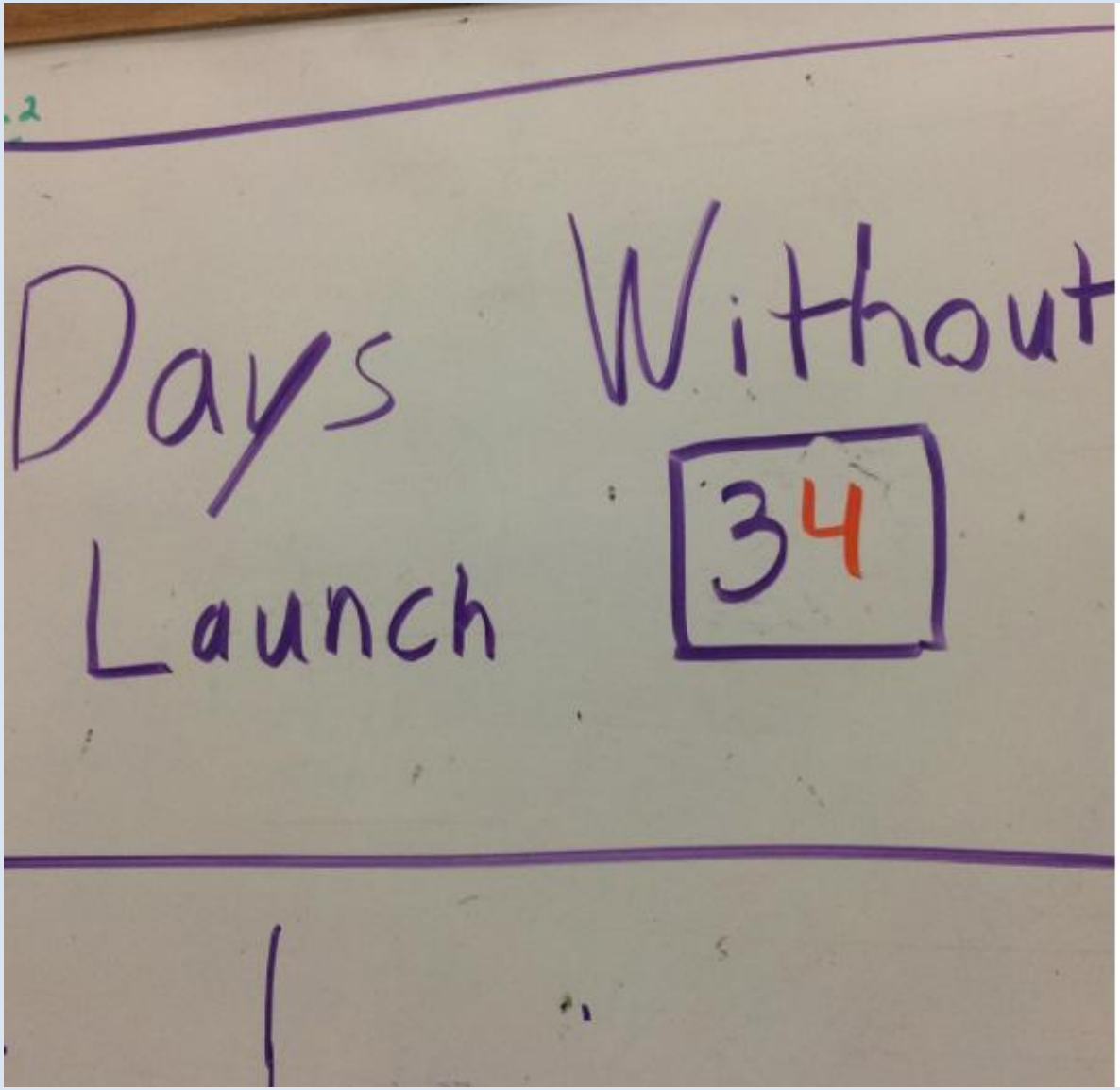
- Deep, wide-field imager between 250-1000 nm
- Towards 0.5 meter class telescope flight on Super Pressure Balloon
  - Weak lensing mass calibrations for hundreds of clusters
  - Deep near-UV wide field imaging
  - Technical pathfinder for future 1.5 m class observatory

SuperBIT Palestine 2016 Test Flight, w/ Hubble 2014



0.5 meter SuperBIT telescope:
Mapping speed ½ x Hubble (5x less res)
1.5 meter (future) SuperBIT telescopes:
Mapping speed 40 x Hubble (2x less res)

Waiting for launch



superbit2017 Follow

kosherking666 😢

laurenemcnamara, thesfield, jacobgie94, ofthegood, bellarosacarla and sr.tanzim like this

2 DAYS AGO

Add a comment...

SPIDER summary

- SPIDER is a completely autonomous payload
  - Electrical power, pointing control and reconstruction, redundant data systems (100 GB/day), cryogenic single-crystal sapphire polarization modulators
- Most sensitive microwave receiver to date
- Weighs a bit over 3.5 tons
  - Over 500 kg cooled to 4 K
  - About 30 kg cooled to 250 mK
- About 15 km of cryogenic wiring
- Hand-made with love (most of the time)
- Subsequent flight planned for 2018

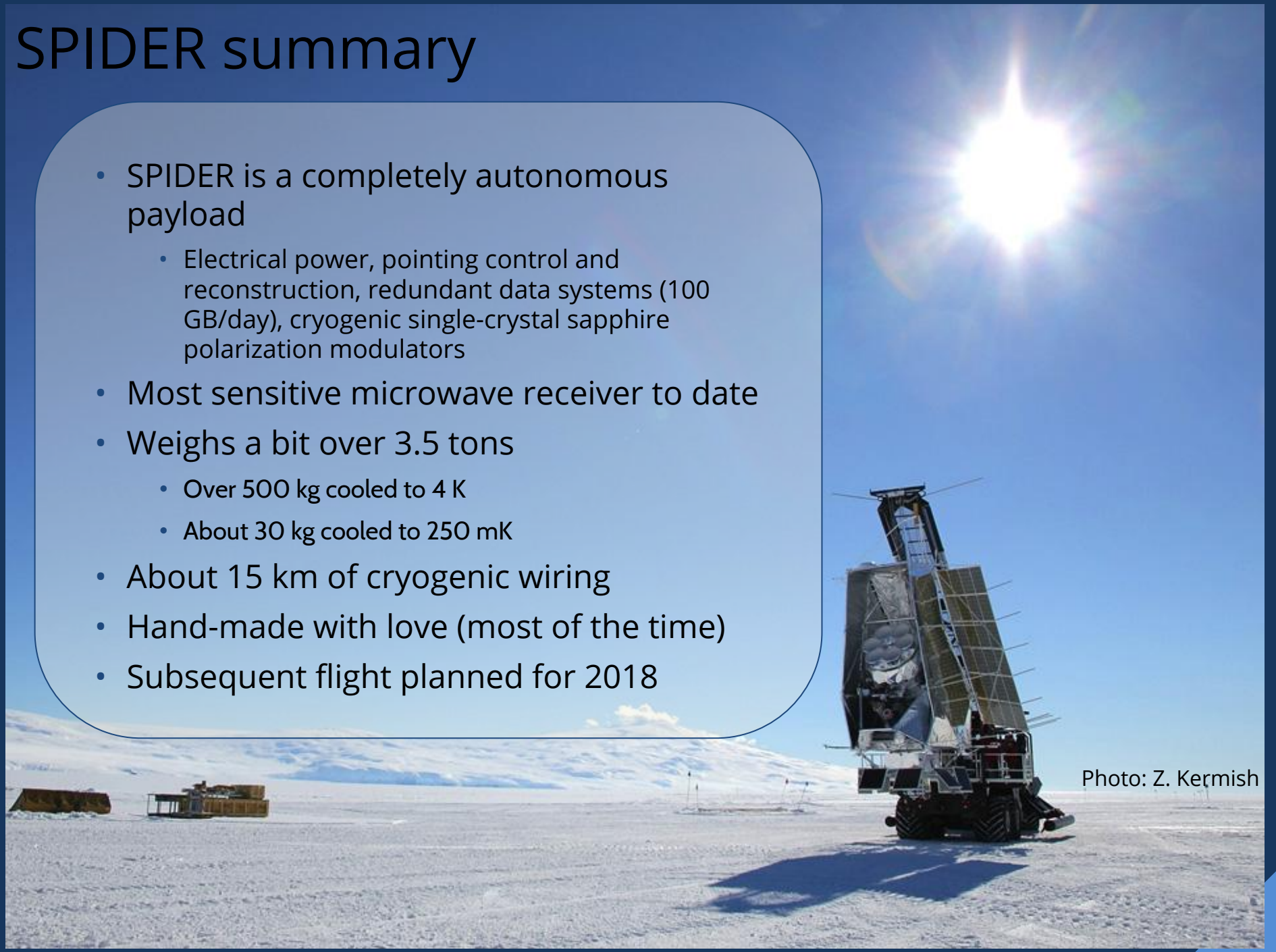


Photo: Z. Kermish


Stay tuned!