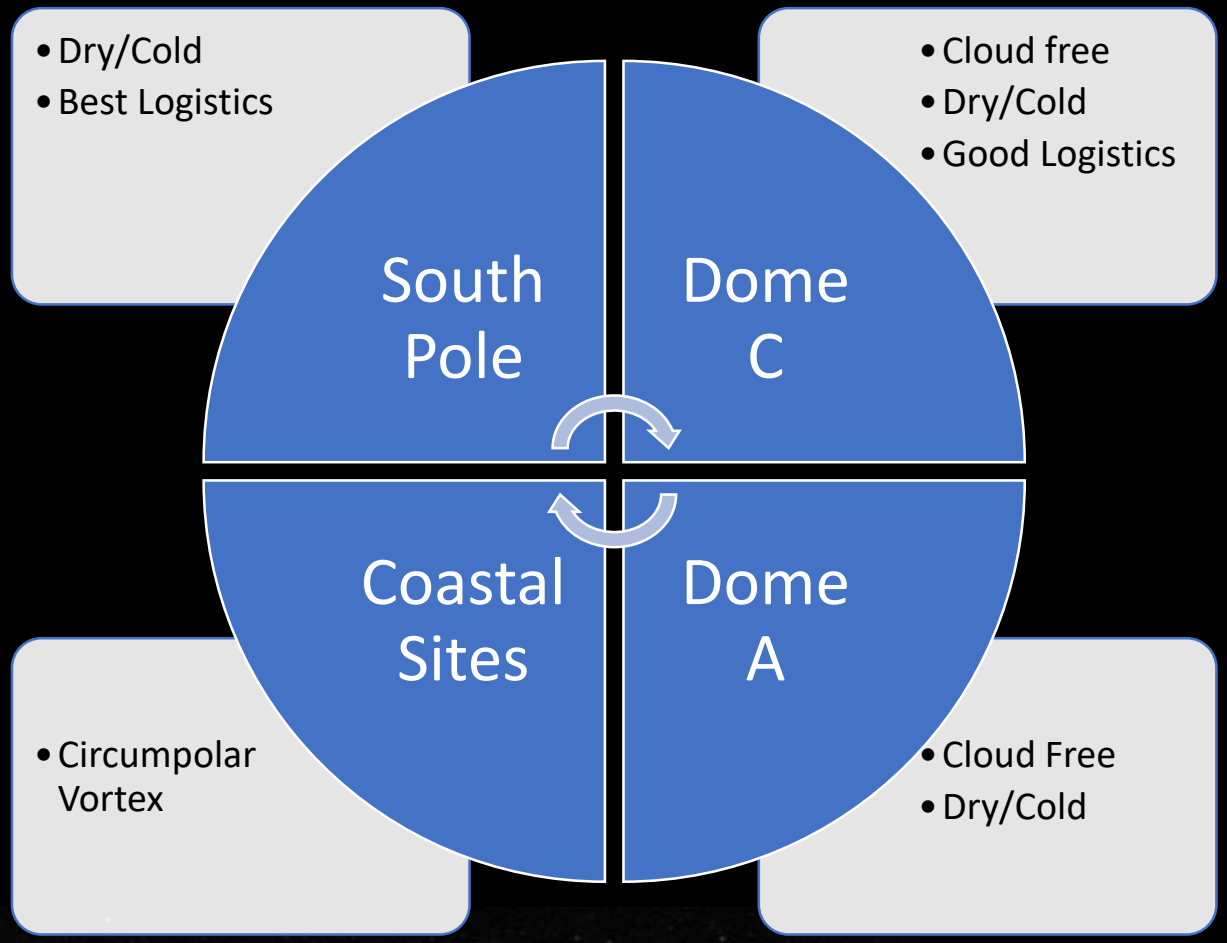
Astronomy

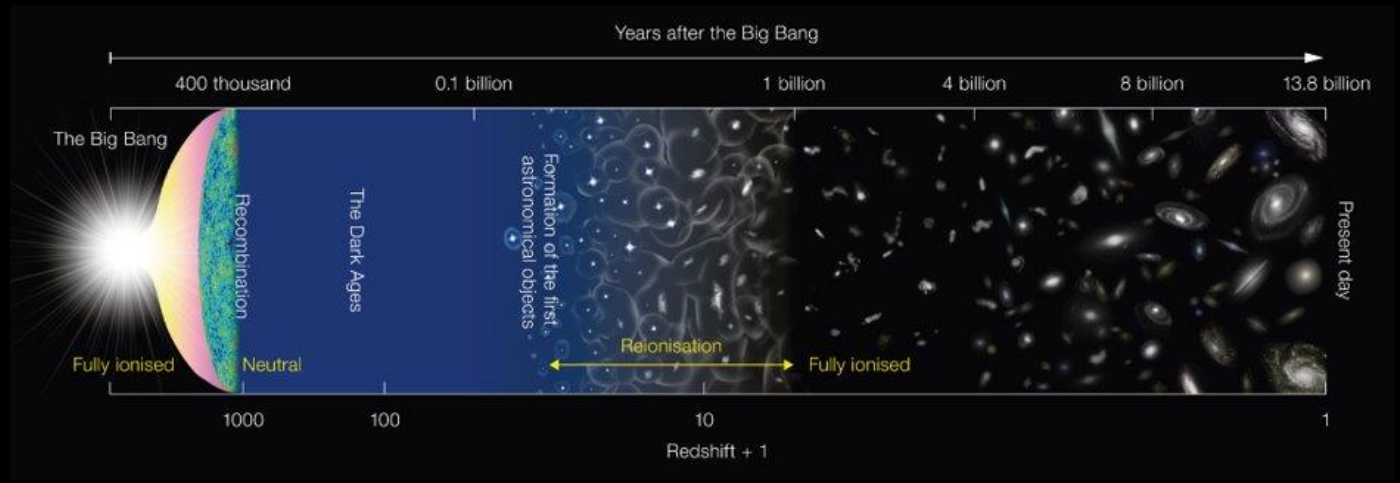
and upper atmosphere

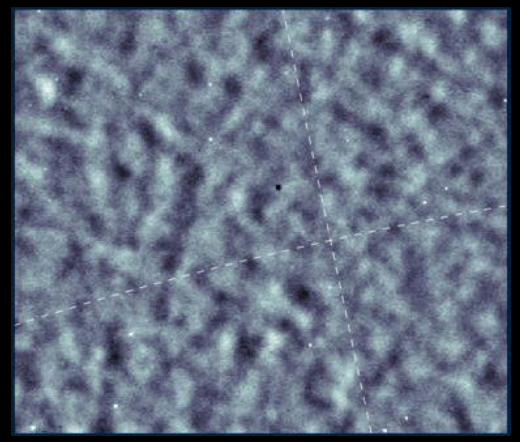
Tony Travouillon (ANU)

Our Ecosystem



The long Wavelengths (sub-mm and Beyond)

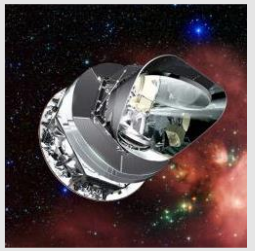




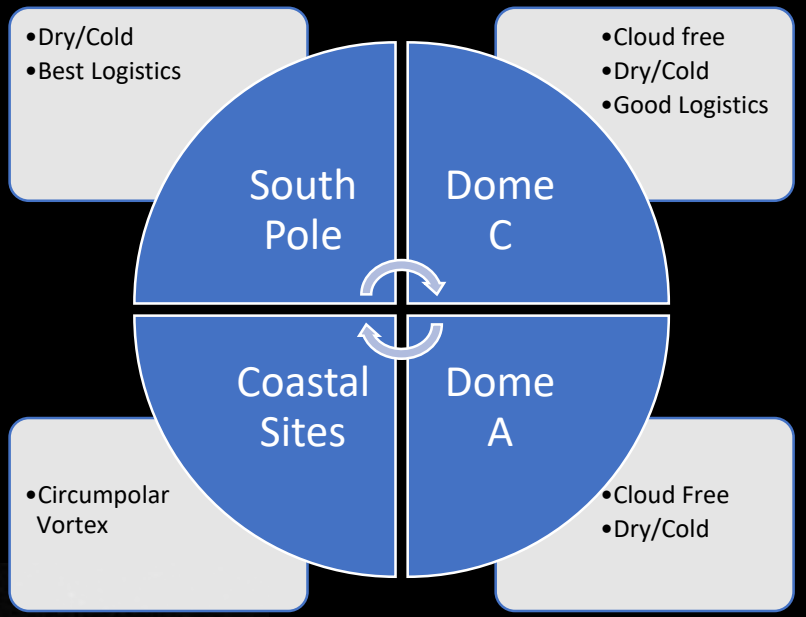
Cosmic Microwave Background Radiation (CMB) observations allow us to study the origin and evolution of the universe, including investigations of ***inflation***, ***neutrinos, dark energy, and beyond!***

SYNERGIES

Advanced Simons Observatory , Chile



Planck



The long Wavelengths (sub-mm and Beyond)

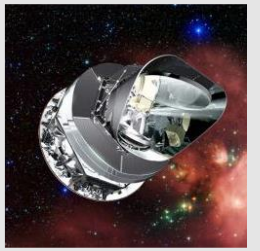
Current Picture: South Pole

- CMB anisotropy: Power spectra and cosmological parameters
- CMB B-Modes: First detection of lensing B-mode polarization; demonstration of
- delensing for improved constraints on inflationary tensor-to-scalar ratio
- CMB lensing: power spectra; cross-correlations; cluster-lensing mass calibration
- Sunyaev-Zel'dovich (SZ): Diffuse kinematic and thermal SZ effect constraints:
- bispectrum, pairwise kSZ, patchy reionization
- Galaxy Clusters: First SZ discovery clusters,
- SZ cluster catalog and cosmology
- High-Redshift Galaxies: Discovered
- population of lensed dusty star forming galaxies
- Transients: mm-wave phenomena (GRBs, FRBs),
- mJy-level monitoring of 1000s of blazars, AGNs
- Participating in the Event Horizon Telescope

The quest to constrain inflationary gravitational waves continues, using data up to 2018 gives $r_{0.05} < 0.036$ (95%), $\sigma(r) = 0.009$. This result rules out two entire classes of previously popular inflation models (monomial models and Natural Inflation).

SYNERGIES

Advanced Simons Observatory , Chile



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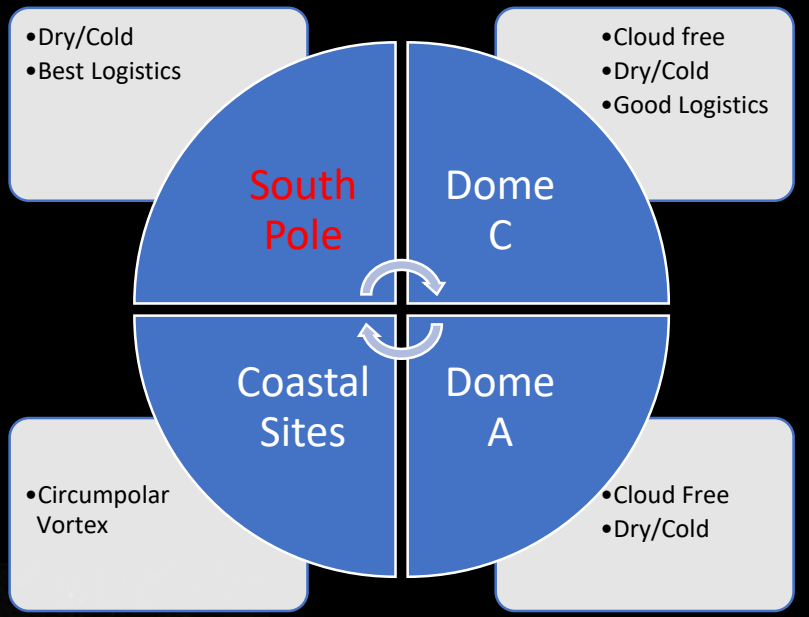


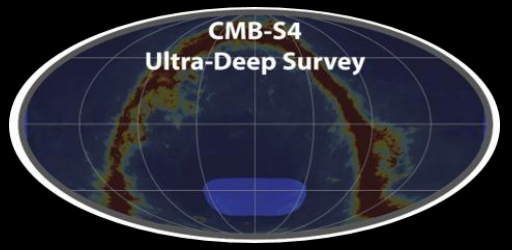
The long Wavelengths (sub-mm and Beyond)

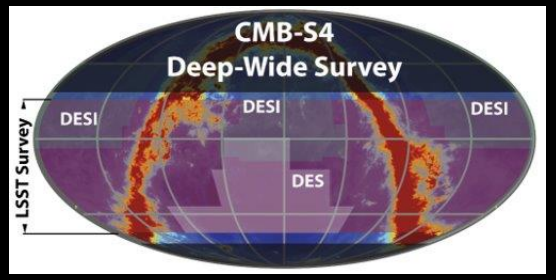
CMB-S4 (Building on the BICEP/Keck Surveys)

- Primordial Gravitational waves and Inflation
- “Light relics”
- Mapping Matter
- Probing Microwave sources

CMB-S4 science goals motivate large & small telescopes sited at the South Pole and large telescopes in the Chilean Atacama desert

The South Pole site is crucial to the ultradeep survey that will detect gravitational waves from inflation or rule out the most favorable theories for the dawn of the universe





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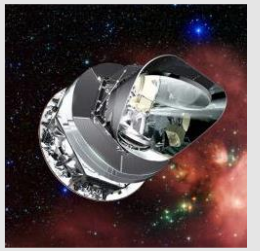
Advanced Simons Observatory , Chile



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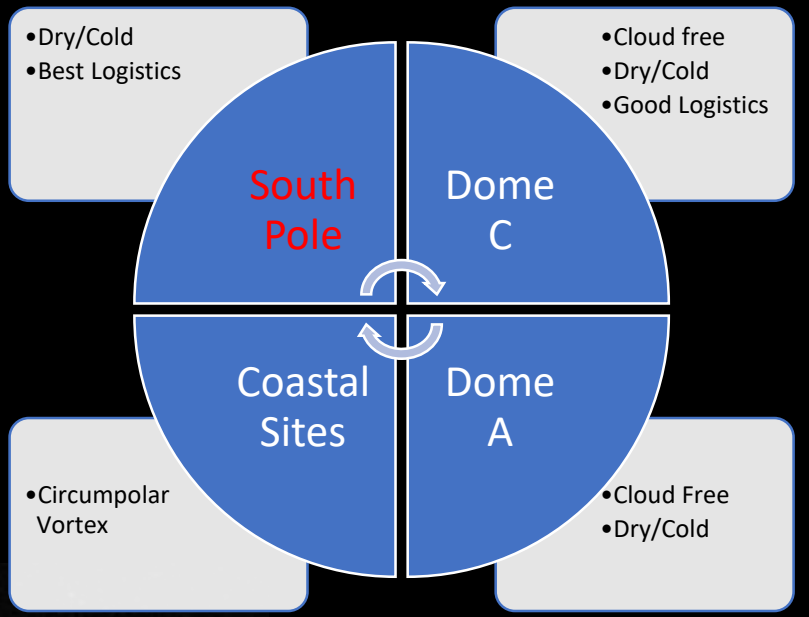


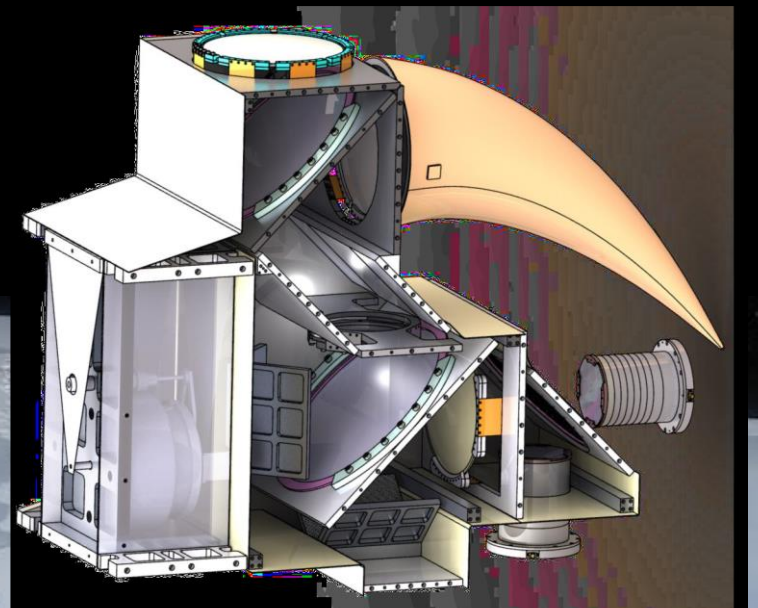
The long Wavelengths (sub-mm and Beyond)

COSMO: Spectral distortion of the CMB

Small departures from a perfect blackbody shape are expected, due to well known as well as exotic physical processes; and can provide information about processes that occurred before and after recombination. See e.g. :

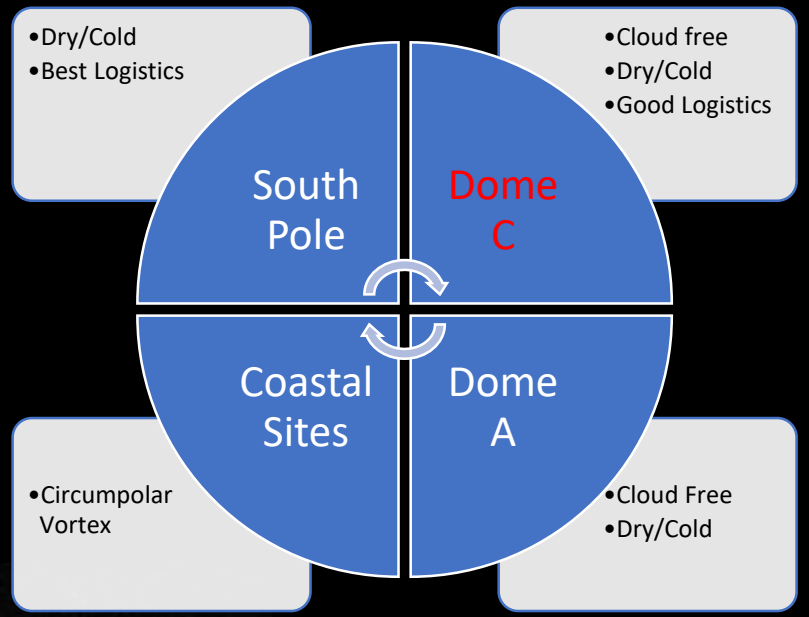
Reionization and structure formation
Adiabatic cooling of baryons and electrons
Damping of small-scale acoustic modes -> inflationary power spectra
Cosmological recombination radiation
Decaying and annihilating particles

Huge complementarity with CMB polarization measurements from the South Pole



SYNERGIES

South Pole CMB Experiments

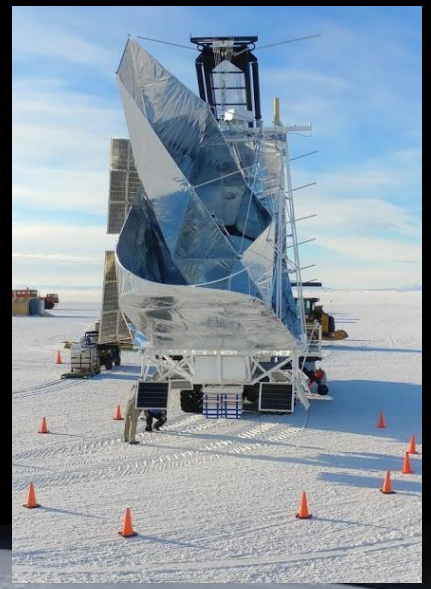


The long Wavelengths (sub-mm and Beyond)

SPIDER, BLAST and OLIMPO

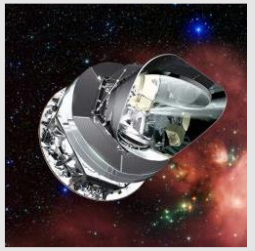
- Missing Baryonic matter
- Galactic clusters
- Polarized dust emission in star forming regions in our Galaxy.
- Polarized dust emission in low dust regions for CMB polarization foregrounds

Critical link between CMB from South Pole/Dome C and ALMA's high-resolution mapping



SYNERGIES

ALMA



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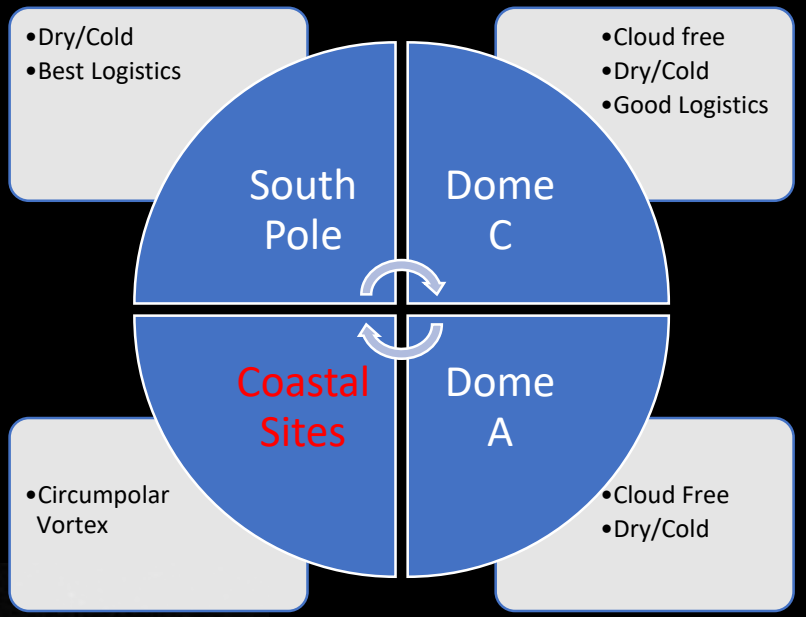


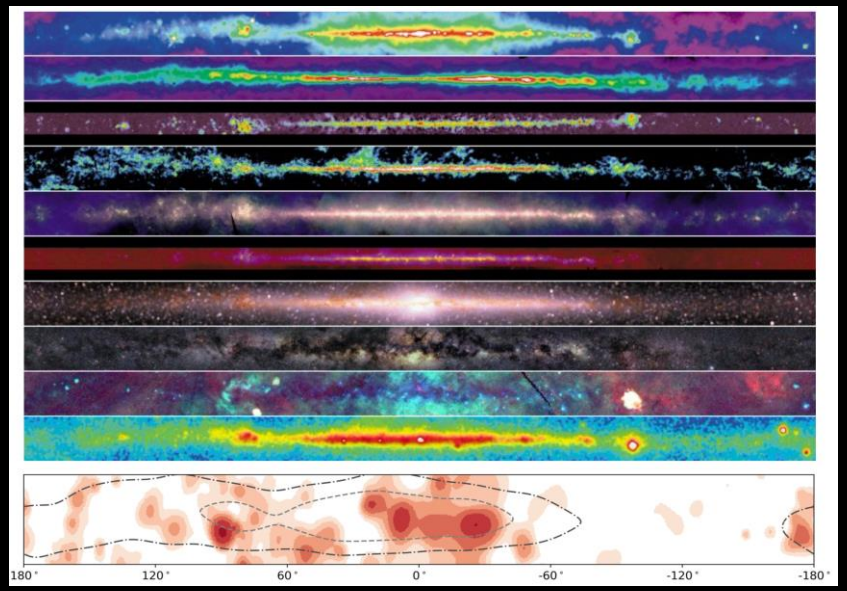
High Energy Particles

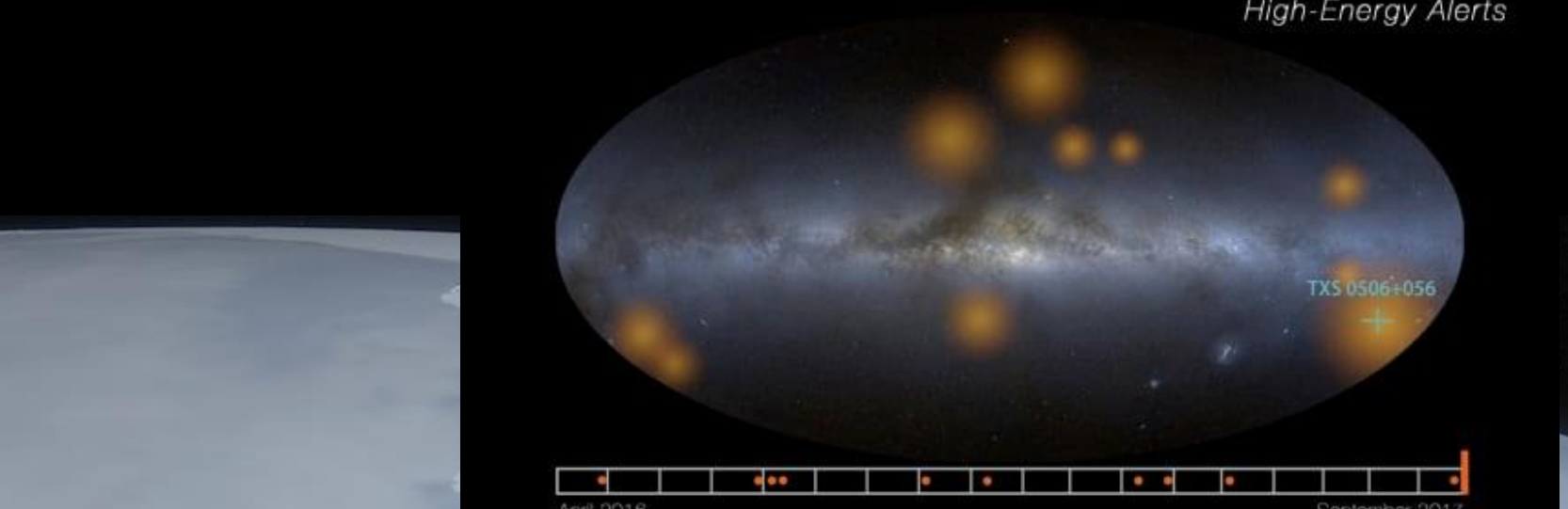
Icecube

Neutrinos as messenger particles:

- electrically neutral
- unabsorbed
- track protons (that produce pions that decay into neutrinos)
- reveal the sources of cosmic rays

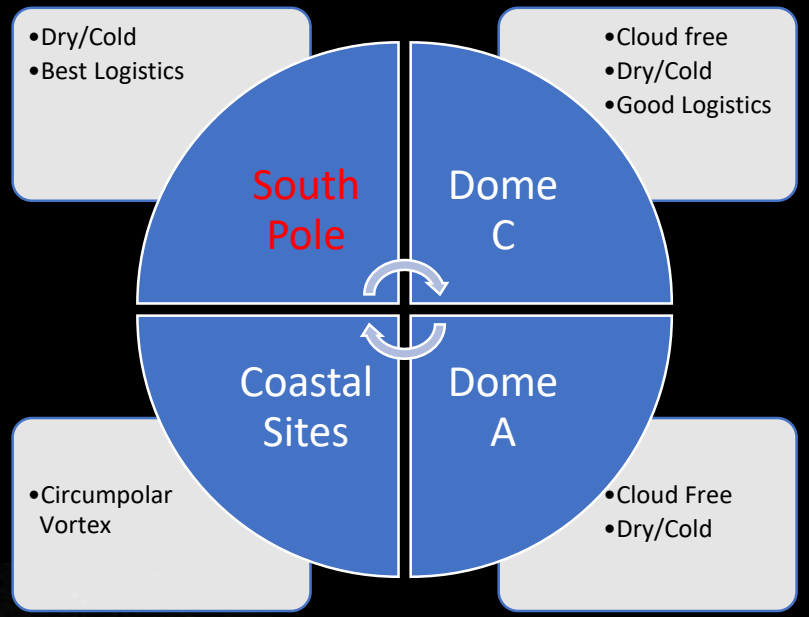
Now a fully fledged multi messenger observatory with single identifications and full mapping of the Milkyway





SYNERGIES

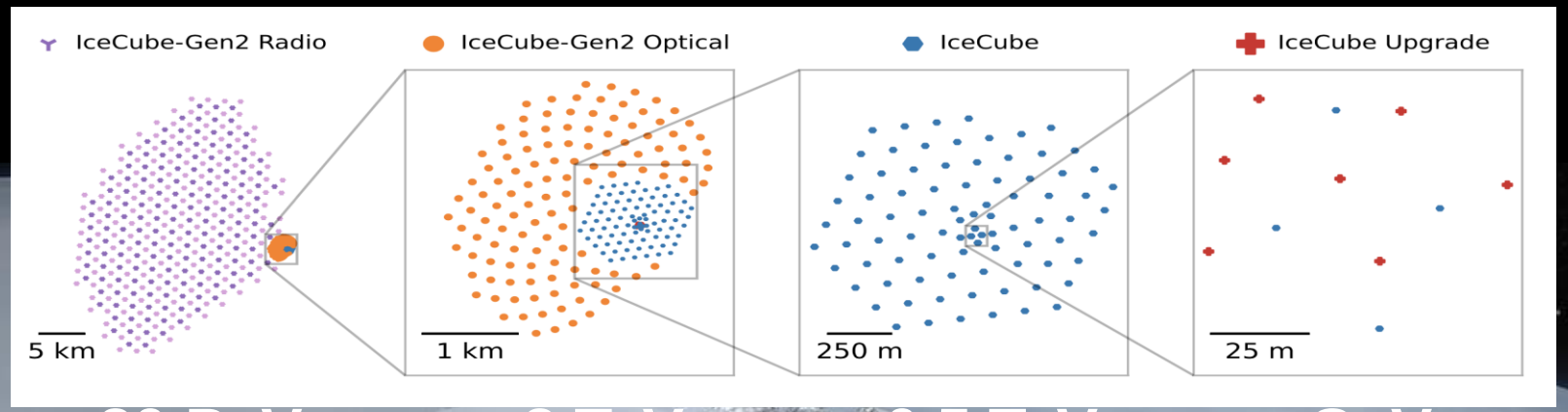
Radio Neutrino Observatory, Greenland



High Energy Particles

Icecube-Gen 2 (2026)

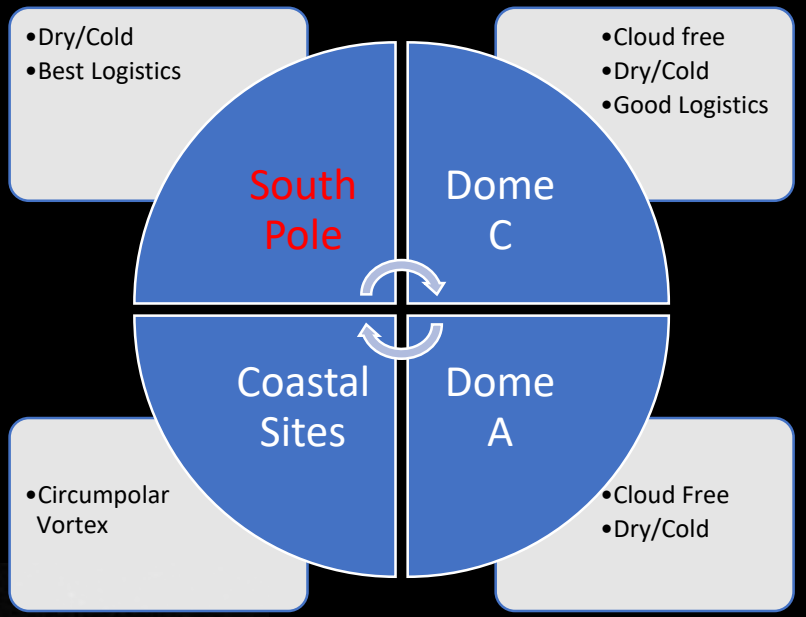
- Increase energy coverage (both low and high), resolve the Tev to Eev neutrino sky
- Investigate cosmic particle acceleration through muli-mesenger observations
- Reveal sources, and propagation of the high energy particle universe
- Further probe fundamental physics (Neutrino Oscillation)



>30 PeV > 3 TeV >0.5 TeV > GeV

SYNERGIES

Radio Neutrino Observatory, Greenland

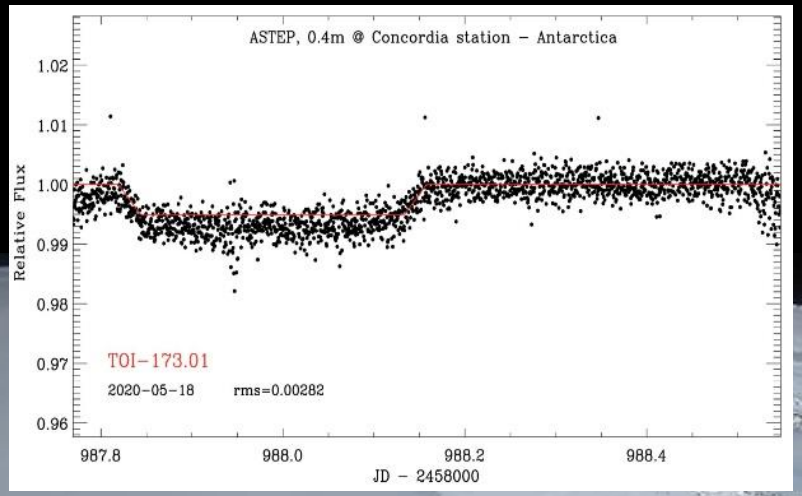


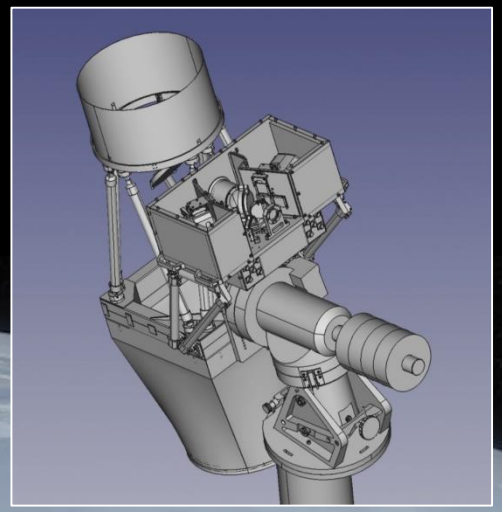
Optical Wavelengths

ASTEP

Follow-up transiting planets

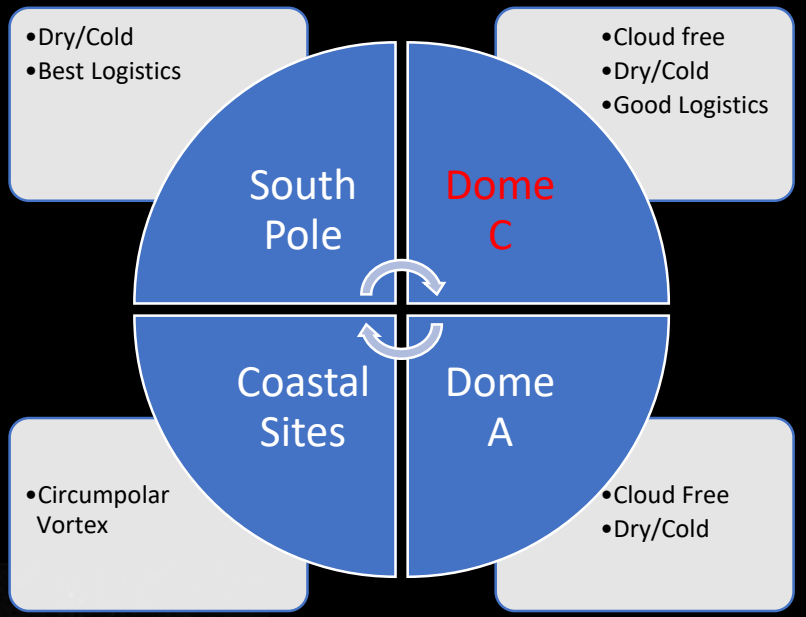
- Long time-base is extremely useful for far-away planets with long transit times
- Keeping track of ephemerides is crucial for future observations with JWST, ARIEL (even PLATO)
- Continuous Southern viewing zone of TESS, JWST is easily accessible from Antarctica, not from other latitudes





SYNERGIES

TESS



Optical Wavelengths

AST3

Time Domain Astronomy (Exo planets, Supernova, GRB, …)

- Survey telescopes (50cm x 3)
- Supernova survey completes, 3500 variables detected including new variables)
- Desire to move to the Infrared

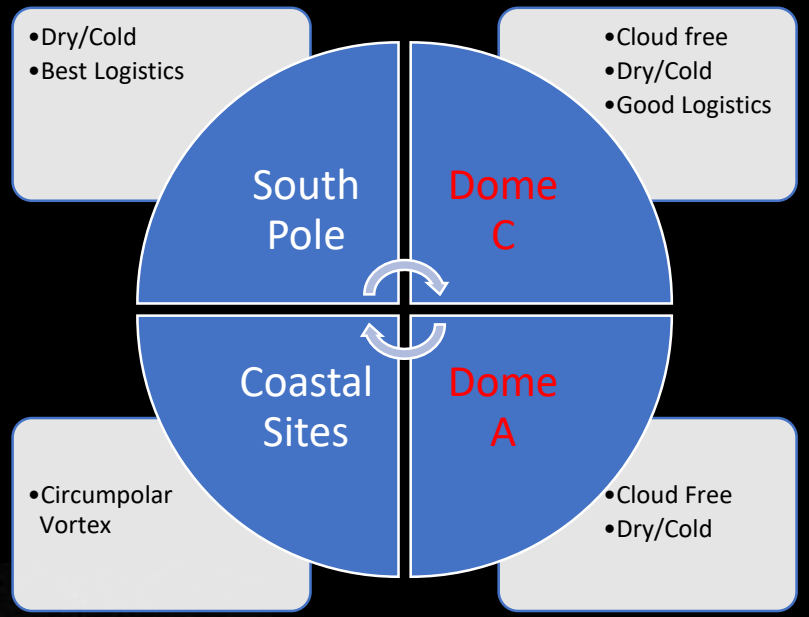
ITM

80cm aperture, two usable foci

- Coming back to life this year
- Perfect platform for dedicated experiment and IR pathfinder
- Used for Optical Comms?

SYNERGIES

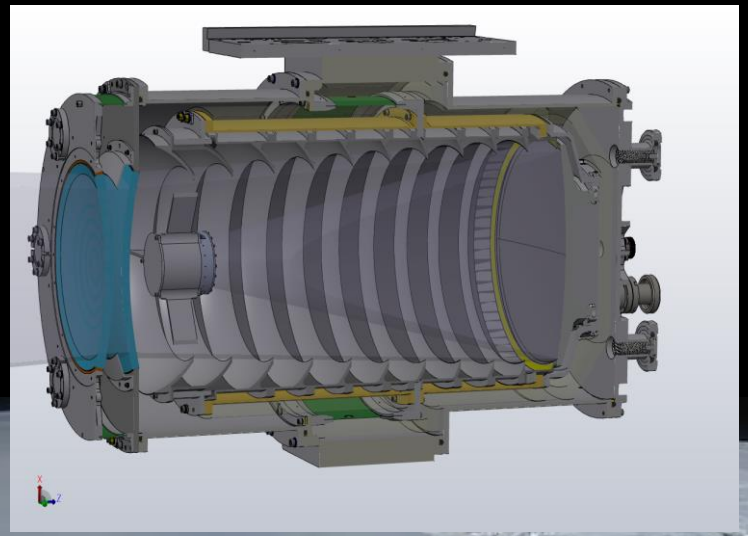
South Pole CMB Experiments

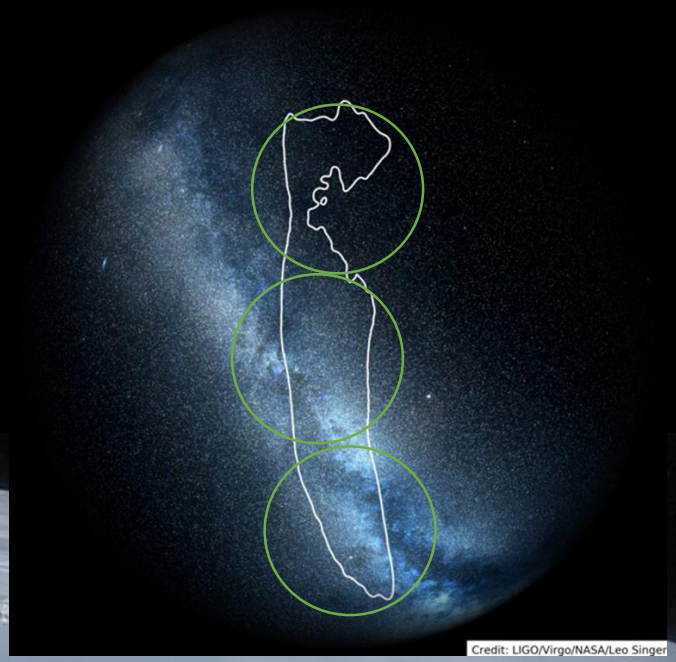


Infrared

Cryoscope

- Time Domain, IR surveyor, 1m diameter, 50 sq. deg filed-of-view
- Equivalent Volumetric speed as VRO in the k-band
- Built upon leveraged expertise of IR surveyors in California and Australia
- Prime capability for Gravitational wave counterpart detections
- Unmatched for surveying the galactic plane
- Quarter-scale pathfinder in construction (IPEV proposal for 2025 deployment)

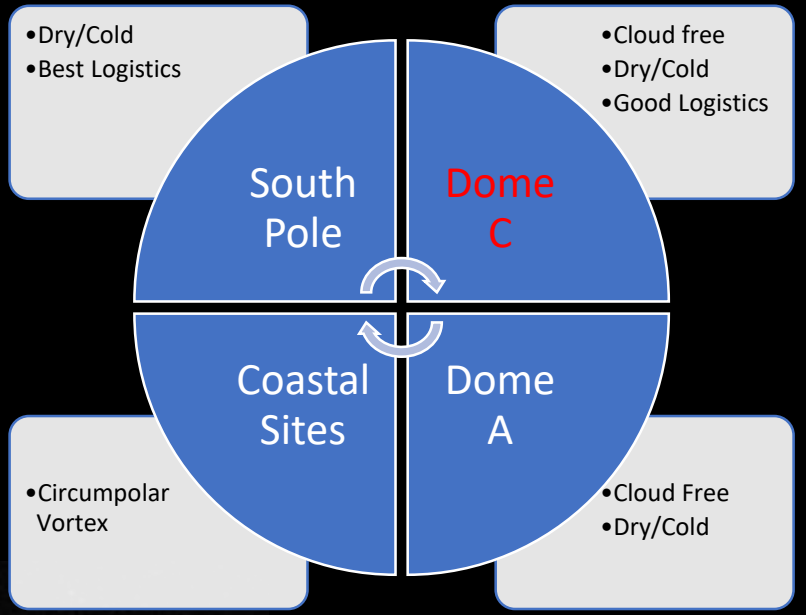




SYNERGIES

Vera Rubin Observatory

LIGO



Upper Atmosphere and Solar observations

Magnetometer networks -> currents

GNSS occultation receivers -> ionospheric irregularities and tomography

Ionosonde networks -> ionospheric structure and dynamics

Optical instruments
- **monochromatic and colour filter auroral imagers ->** energy of electron precipitation, large scale structure of aurora
- **OH imagers -> gravity waves**
- **Fabry-Perot interferometers -> winds and dynamics**

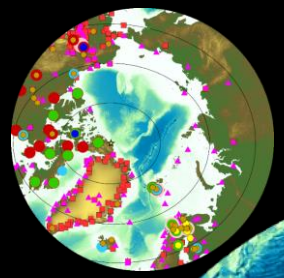
Imaging radars including
- **PANSY in Antarctica**
- **EISCAT_3D, MAARSY and others in the Arctic**

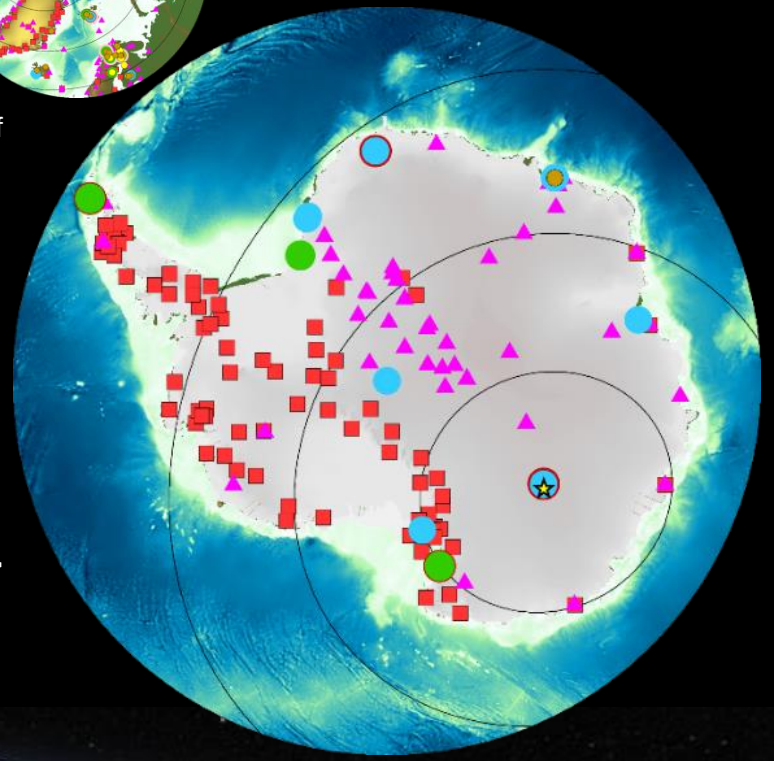
SuperDARN -> Large scale ionospheric convection and waves
Riometer networks -> Ionisation in the lower ionosphere / mesosphere region

GNSS networks (i.e. POLENET, ANET, IGS, national stations) -> Tropospheric water vapour retrieval, variability and evolution

Microwave radiometers, infrared sounders (i.e. AIRS, AMSU-B,,MHS, GOCE-2) -> Integraterd Water Vapour

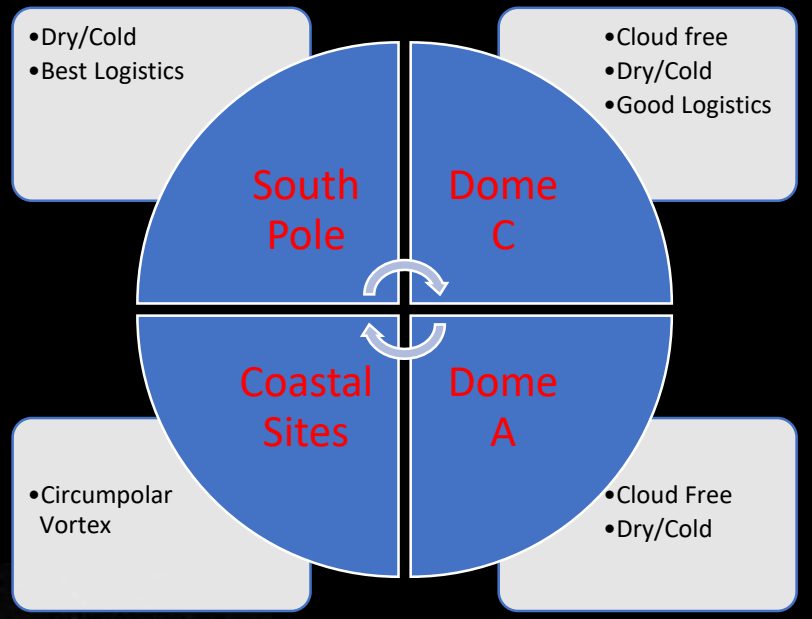
Satellites





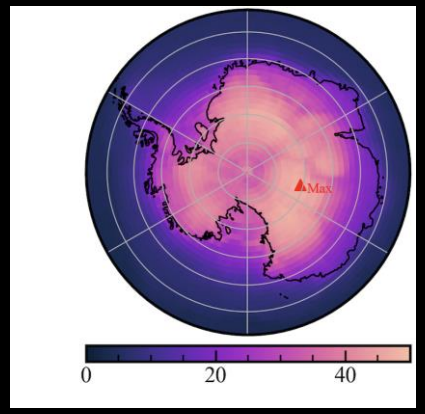
SYNERGIES

Parker Solar Probe

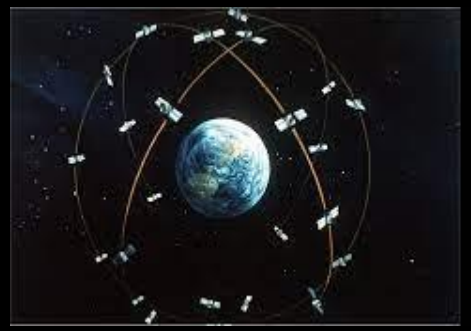


Emerging Technologies

Optical Communications
- Up to 40Tb per day in places like Dome C
- Can use local capabilities (telescopes)
- Support Deep space missions

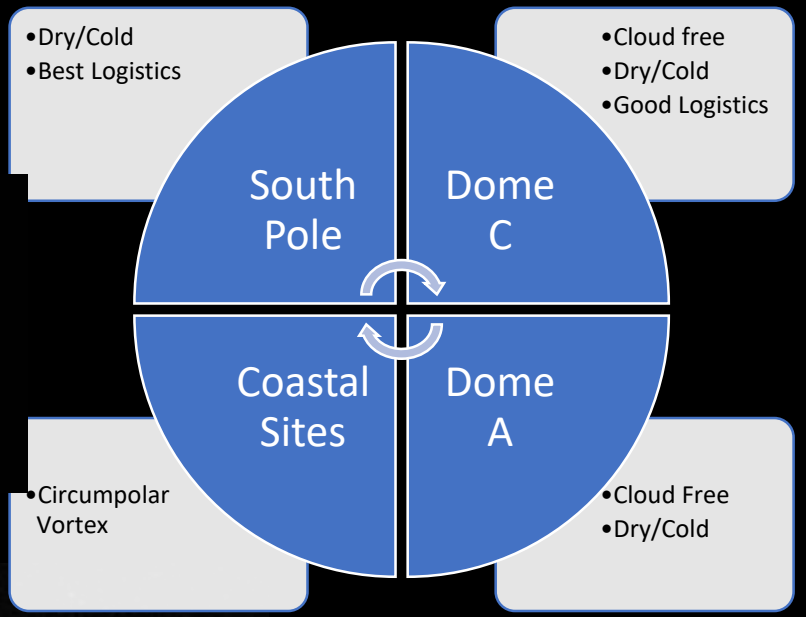


Space Situational Awareness
- Ideal for observation of Polar obits
- Leverages existing facilities



SYNERGIES

Psyche mission



Concluding Remarks

How to find success in Antarctic Astronomy?

- Strong community support of science driven experiments
- Support of National Programs is critical (competition with ESO)

Scale and leveraging

- Is an experiment limited by logistical capabilities or worth expending the logistical support for?
- Have we considered leveraging experiments together? (Tower, communication, etc…)

SYNERGIES

South Pole CMB Experiments