The CCAT-prime Project

CCAT-prime will be a 6-meter (20-feet) diameter telescope with a surface accuracy of ~10 microns (0.004 inches) and located at 5600 meter (18,400 ft) elevation on Cerro Chajnantor in the high Atacama desert of northern Chile. Its novel optical design will deliver a high-throughput wide-field-of-view telescope capable of illuminating more than 100,000 detectors so that large areas of the sky can be scanned rapidly. The high, dry site offers superb observing conditions, yielding routine access to the 350 micron window as well as improved performance at longer wavelengths. Under the best conditions, observations in the 200 micron window will be possible. CCAT-prime is specifically designed to measure the motions, temperatures and transparencies of distant galaxy clusters, to trace the appearance of the first population of star-forming galaxies through intensity mapping of their [CII] emission in the epoch of reionization, and to probe multiple spectral line tracers of the interstellar medium over a range of environments in the Milky Way, the Magellanic Clouds and other nearby galaxies. It will also be a next-generation Cosmic Microwave Background observatory.

Superb observing site

Over the last decade, CCAT astronomers have studied the topography and weather conditions in the Chajnantor region via campaigns of weather balloon launches to measure the temperature, pressure and wind and the deployment of a device to measure the amount of water vapor in the atmosphere. The site at 5600 meters has significantly better transparency to submillimeter radiation than the 5000 meter plateau below. Despite its extreme altitude, the CCAT-prime site can be reached by truck.

Crossed-Dragone Telescope Design

The novel Crossed-Dragone optical telescope provides:

- Up 8° wide field-of-view
- Flat focal plane
- Low emissivity for high sensitivity
- Accommodate > 10^4 detectors at longer wavelengths and even more at shorter.
- Design also adopted by Simons Observatory

CCAT-prime exploits the latest submillimeter detector technologies. The first light camera - PrimeCam - will have 7 sub-cameras to: reveal high redshift starforming galaxies (350 μm), measure the Sunyaev-Zel’dovich (kSZ) effect; and reveal the process reionization (EoR) with Fabry-Perot interferometers.

Stage IV CMB platform

- Could map the CMB at 10 times the speed of current telescopes.
- Submm coverage will provide galactic foreground removal for other CMB efforts.
- Many synergies with planned Simons Observatory.
- CCAT-prime will be a leading player in next generation CMB science.

Half of Cornell’s contribution to CCAT-p has been provided by Fred Young ’64, BME ’65, ME(mech.) ’66, MBA ’66.

Studies of the Sunyaev-Zel’dovich Effect

- S-Z Effect: Distortions in the Cosmic Microwave Background (CMB) spectrum are seen when CMB photons travel through the hot intra-cluster medium of clusters of galaxies along the line of sight. Kinds of distortions are predicted:
  - tSZ (thermal): black
  - rSZ (relativistic): cyan
  - lSZ (kinetic): red

- CCAT-prime will make observations at many wavebands from 350 microns to 3.3 millimeters simultaneously, allowing precise measurement and separation of all three S-Z effects: thermal, relativistic and kinetic.
- Measurements of the kinetic S-Z will impose constraints on models of dark energy and modified gravity through precision studies of 1000 clusters of galaxies with 100 km/s accuracy.
- Additionally, these studies will also provide a measurement of the sum of neutrino masses, another important cosmological prediction.

Intensity Mapping of the First Star-forming Galaxies

- After the CMB photons were emitted, the Universe entered the "Cosmic Dark Age", when hydrogen atoms were neutral and there were no sources of light (stars, galaxies, quasars).
- Then a few hundred million years after the Big Bang, the first star forming galaxies lit up "Cosmic Dawn" and reionized the hydrogen – the Epoch of Reionization (EoR).
- CCAT-prime will be able to watch this reionization process by detecting the aggregate emission from ionized carbon ([CII]) in those galaxies as more and more of them appear over the redshift range 9 to 3.5, corresponding to 500 million to 1.8 billion years after the Big Bang.

Galactic Ecology of the Dynamic Interstellar Medium

- Spectral line mapping of fine structure and mid/high-excitation CO lines provides diagnostics of physical conditions and motions of interstellar clouds.
- Gas temperatures, densities and velocities will trace the processes by which stars and planets form in different environments in the Milky Way including the Galactic Center, the Magellanic Clouds and other nearby galaxies.
  - High, dry site provides unique access to shortest submillimeter wavelengths.
  - Builds on the SOFIA airborne observatory (2.5m telescope) with better resolution, much more observing time.

Canadian Consortium

Figure from Robertson et al. 2010, Nature 468, 49

Design by Vertex Antennentchnik GmbH

Layout of CHAI instrument being built at University of Cologne.