Low Frequency All-sky TemperaTure Experiment "LATTE"

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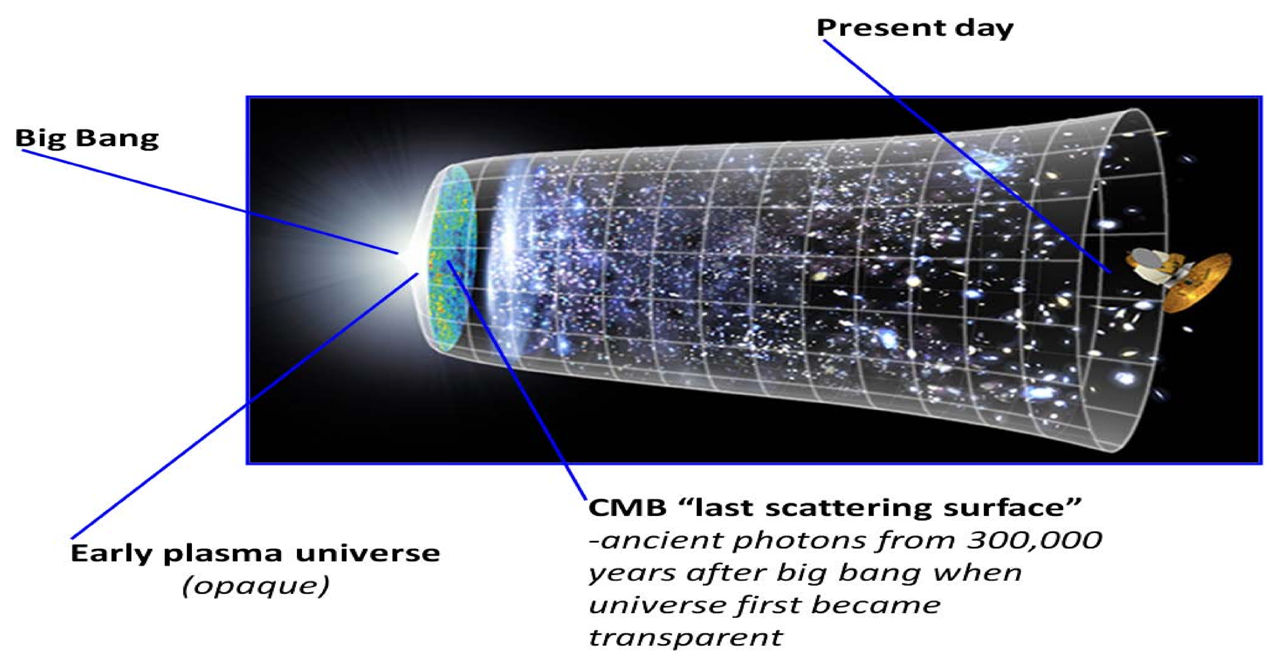
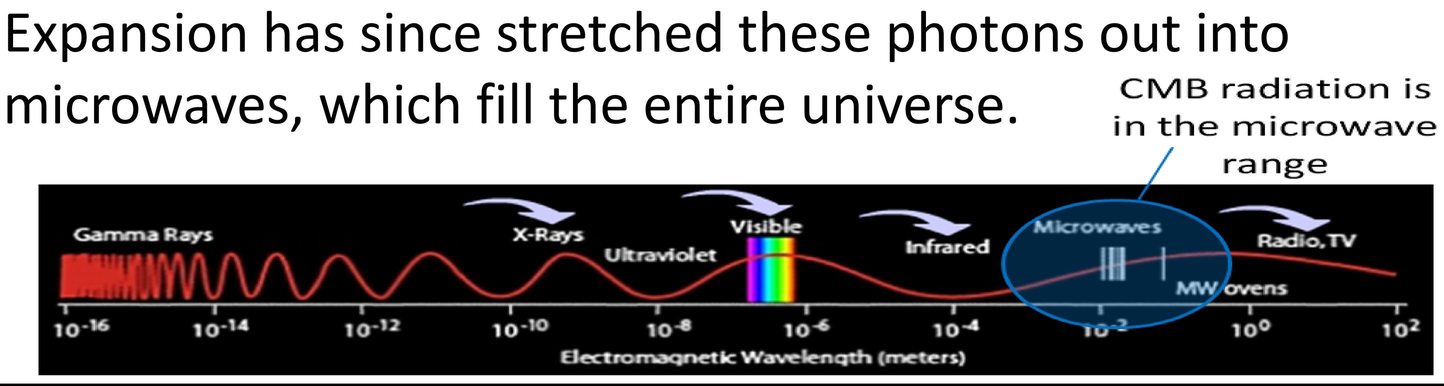
Cosmic Microwave Background: The early universe was made of dense, hot, opaque hydrogen plasma. About 400,000 years after the big bang, the universe expanded and cooled down enough for protons and electrons to combine and form neutral hydrogen, making the universe transparent and allowing light to begin traveling freely for the first time.

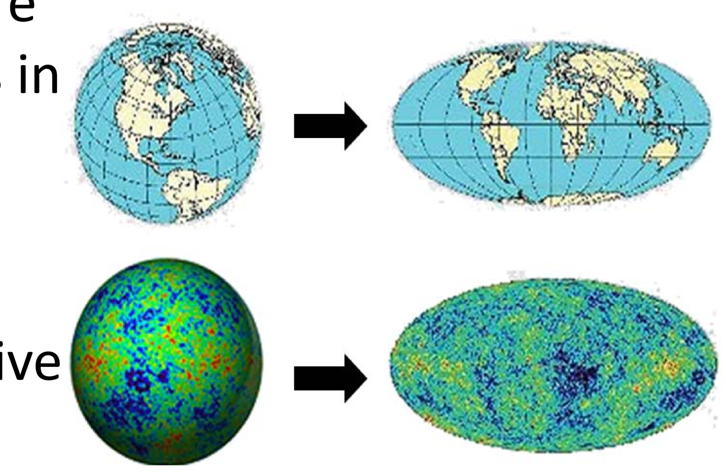
These are the most ancient photons we will ever see, since we can't see anything before the universe became transparent.



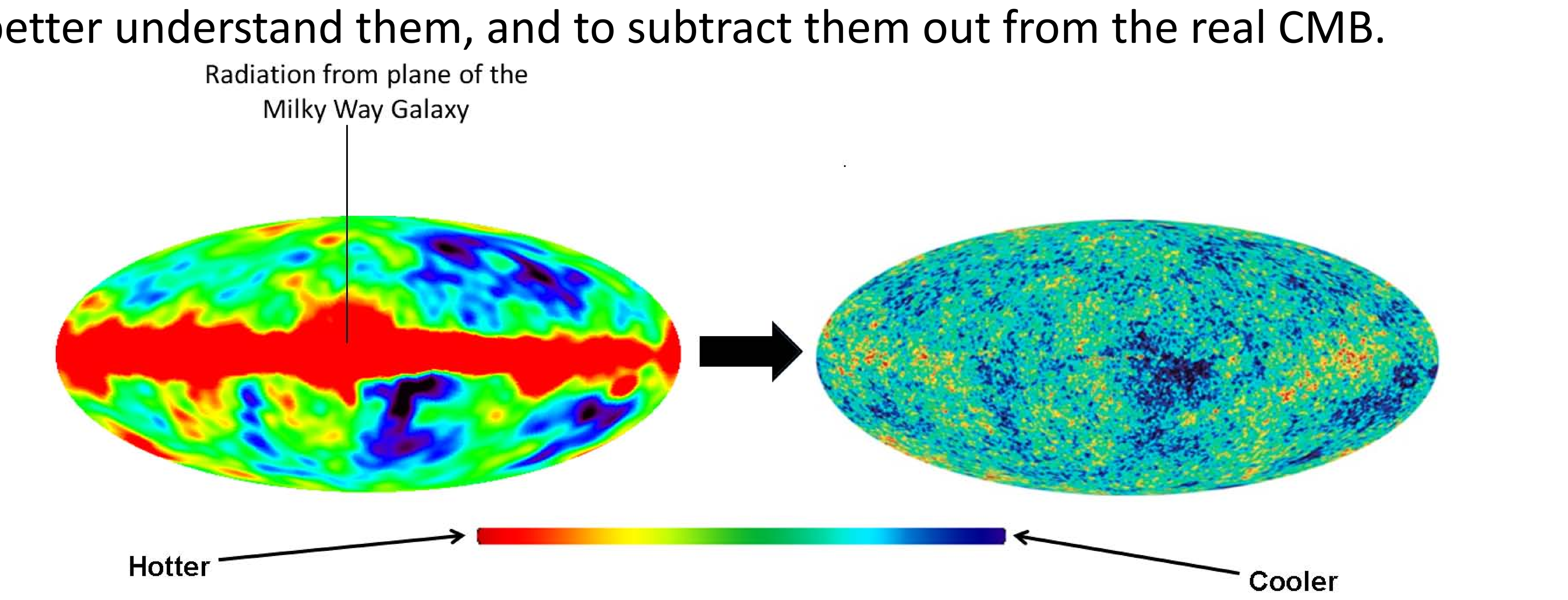
Expansion has since stretched these photons out into microwaves, which fill the entire universe.



Big picture: To map temperature variations in the Cosmic Microwave Background (CMB). Temperature variations correspond directly to density variations in the plasma of the early universe. Understanding these variations, or "anisotropies" can help us answer many cosmological questions about the origins and underlying physics of the universe we live in, which will ultimately lead to technological advances in many areas of science and engineering.



LATTE: the plane of our Milky Way galaxy emits extra low-frequency microwave radiation that prevents accurate mapping of the CMB. The goal of LATTE is to design and build a microwave telescope to study these frequencies; both to better understand them, and to subtract them out from the real CMB.

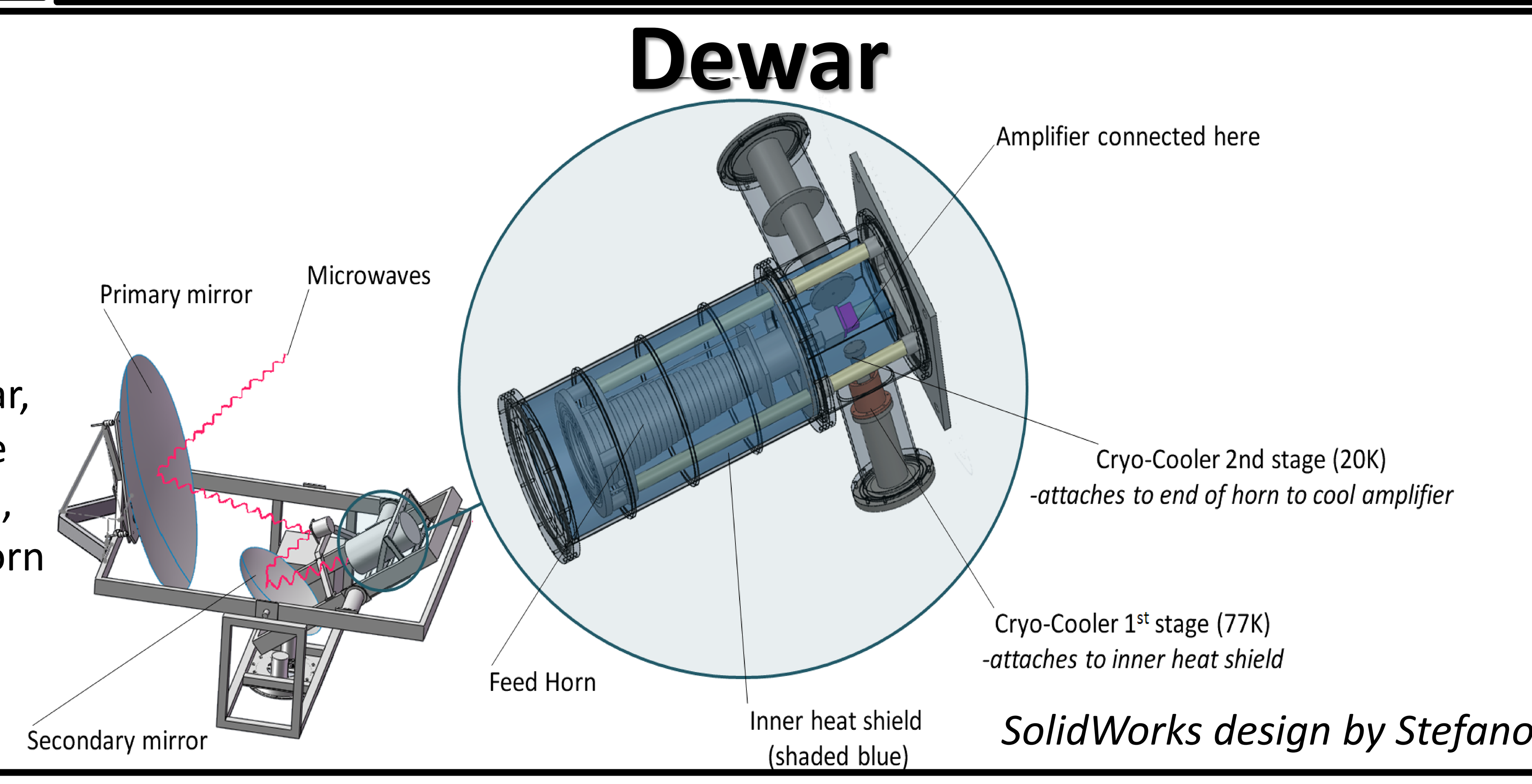


Dewar: Microwaves bounce off mirrors into a feed horn, where they are then amplified. The amplifier needs to be very cold (20 Kelvin) in order to minimize thermal noise. To accomplish this, we are building a heat shielded, vacuum pumped, and cryogenically cooled device called a Dewar.

"Basically a super-cooled thermos."

Radiative Heat Transfer: In order to design an efficient dewar, we need to know how much outside heat is leaking in. There are three heat transfer mechanisms: conduction, convection, and radiation. Conduction is minimized by supporting the horn with fiberglass tubing, and convection is minimized by creating a vacuum inside the dewar. This means most of the heat leakage comes from radiative heat transfer.

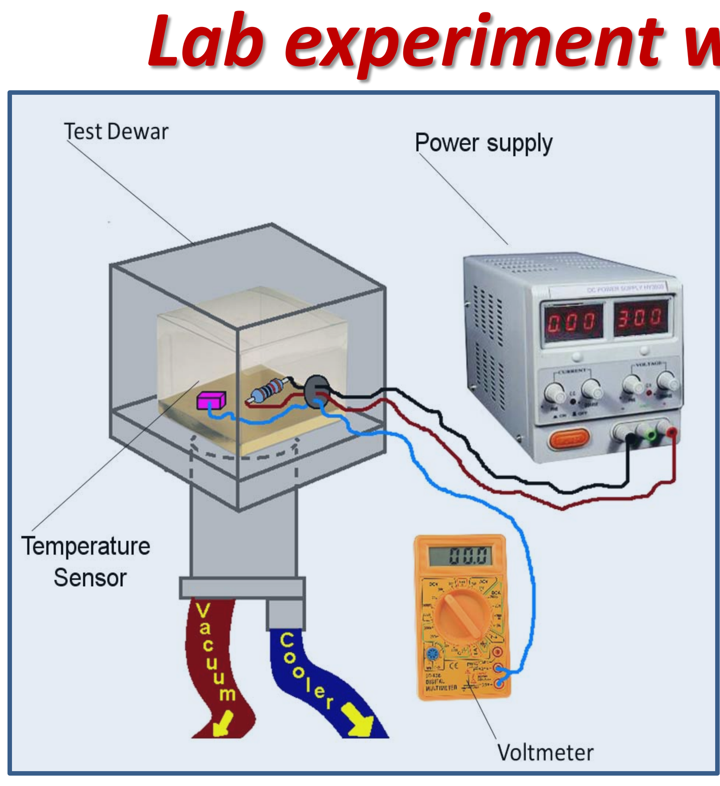
Dewar

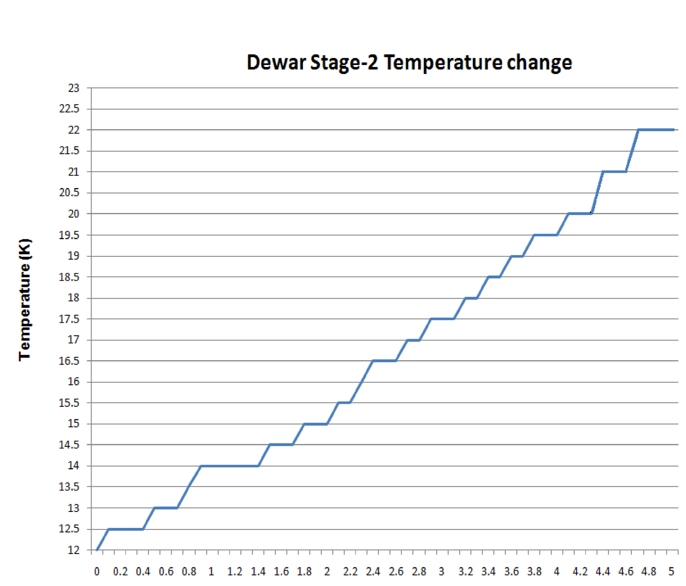


SolidWorks design by Stefano

My Project (*Examples Shown for 77K plate of a test dewar connected to 2nd stage of the cryo-cooler*)

Lab experiment with a test dewar





Procedure

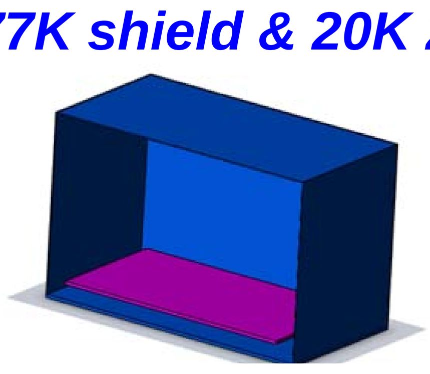
1. Supply varying heat loads to the test dewar by using a power supply to run voltages over a resistor.
2. Record how much voltage there is over the temperature sensor for each heat load. For every voltage value there is a corresponding temperature in Kelvins on the temperature sensor's calibration chart.

Results

This is heat load data from cooling the plate of the test dewar that is connected to the second stage of the cryo cooler. In order to find out how much heat leakage there is I need more than one calibrated temperature sensor so I can get data from both stages at once.

Theoretical Heat Flux Calculation

"77K shield & 20K 2nd stage plate (6 faces)"



Net Heat Flux:
0.003 Watts

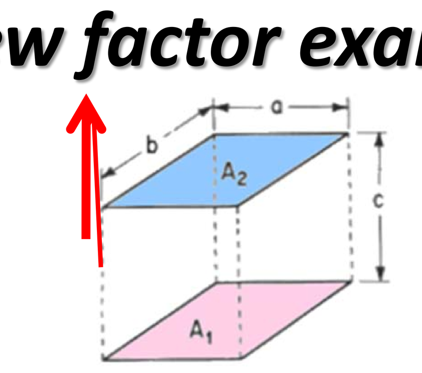
$$\sum_{k=1}^{6}\sum_{j=1}^{6}\left(\frac{\delta_{kj}}{\varepsilon_j}-F_{kj}\right)*q_j=\sum_{k=1}^{6}\sum_{j=1}^{6}\left(\delta_{kj}-F_{kj}\right)*\sigma T_j^{4}$$

"Heat transfer summation equation for 6 surfaces"

- ***j*** and ***k*** represent surfaces that respectively emit and absorb heat
- The goal was to solve for all of the q_j variables; the net heat radiation flux through each unique face of the dewar from all of the other faces.

- We first had to solve for all F_{kj} values, aka "**View Factors**", the fraction of the total heat radiation leaving surface ***k*** that is intercepted by surface ***j***.

View factor example:



$$F_{1-2}=\frac{2}{\pi XY}\left\{\ln\left[\frac{(1+X^2)(1+Y^2)}{1+X^2+Y^2}\right]^{1/2}+X\sqrt{1+Y^2}\tan^{-1}\frac{X}{\sqrt{1+Y^2}}+Y\sqrt{1+X^2}\tan^{-1}\frac{Y}{\sqrt{1+X^2}}-X\tan^{-1}X-Y\tan^{-1}Y\right\}$$

$$F_{12}=0.123445$$

Heat Flux Simulation (in SolidWorks)