Low Frequency All Sky TemperaTure Experiment "LATTE"

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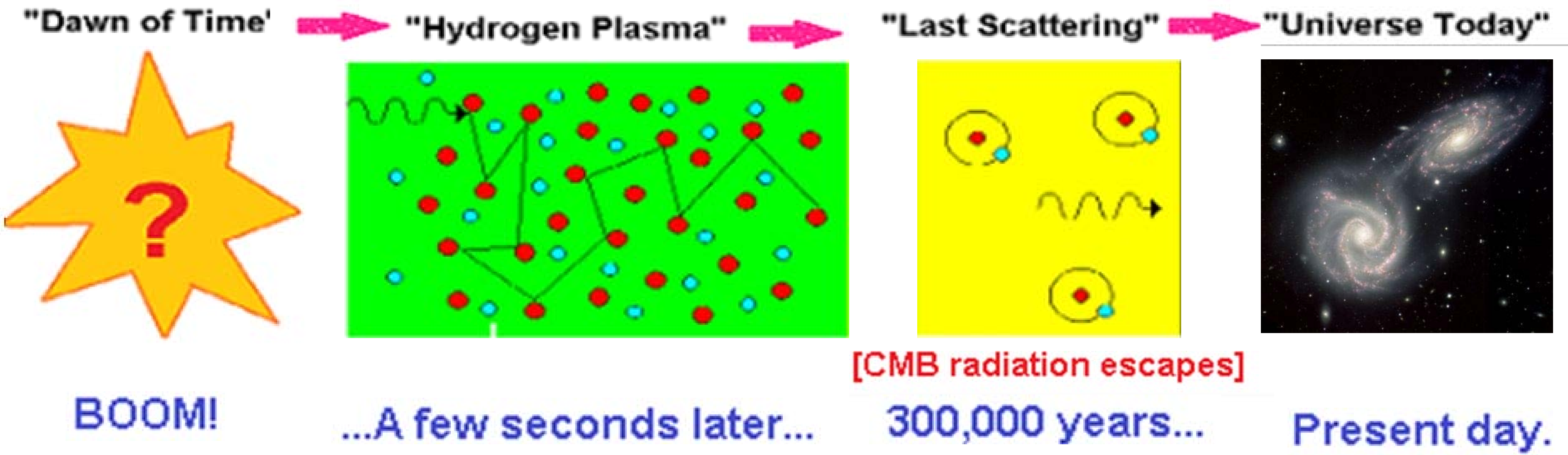
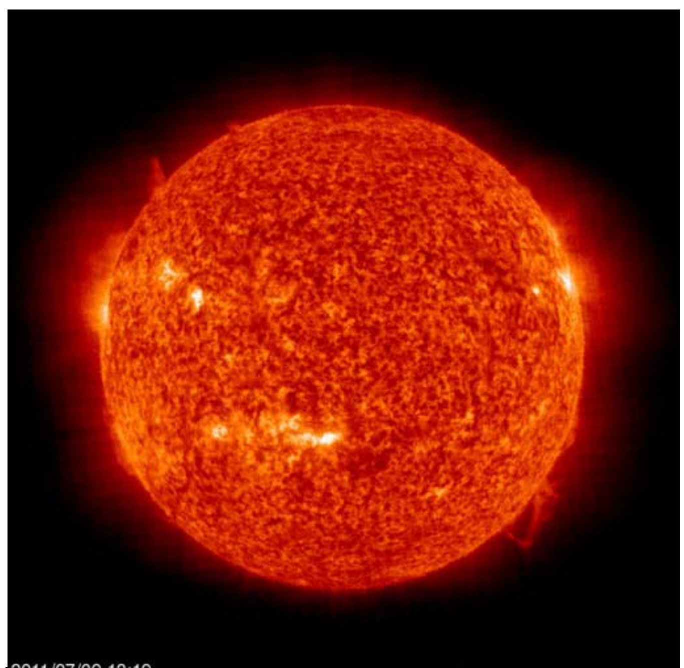
- Mentor: Ishai Rubin
- Funding: The Ax Foundation

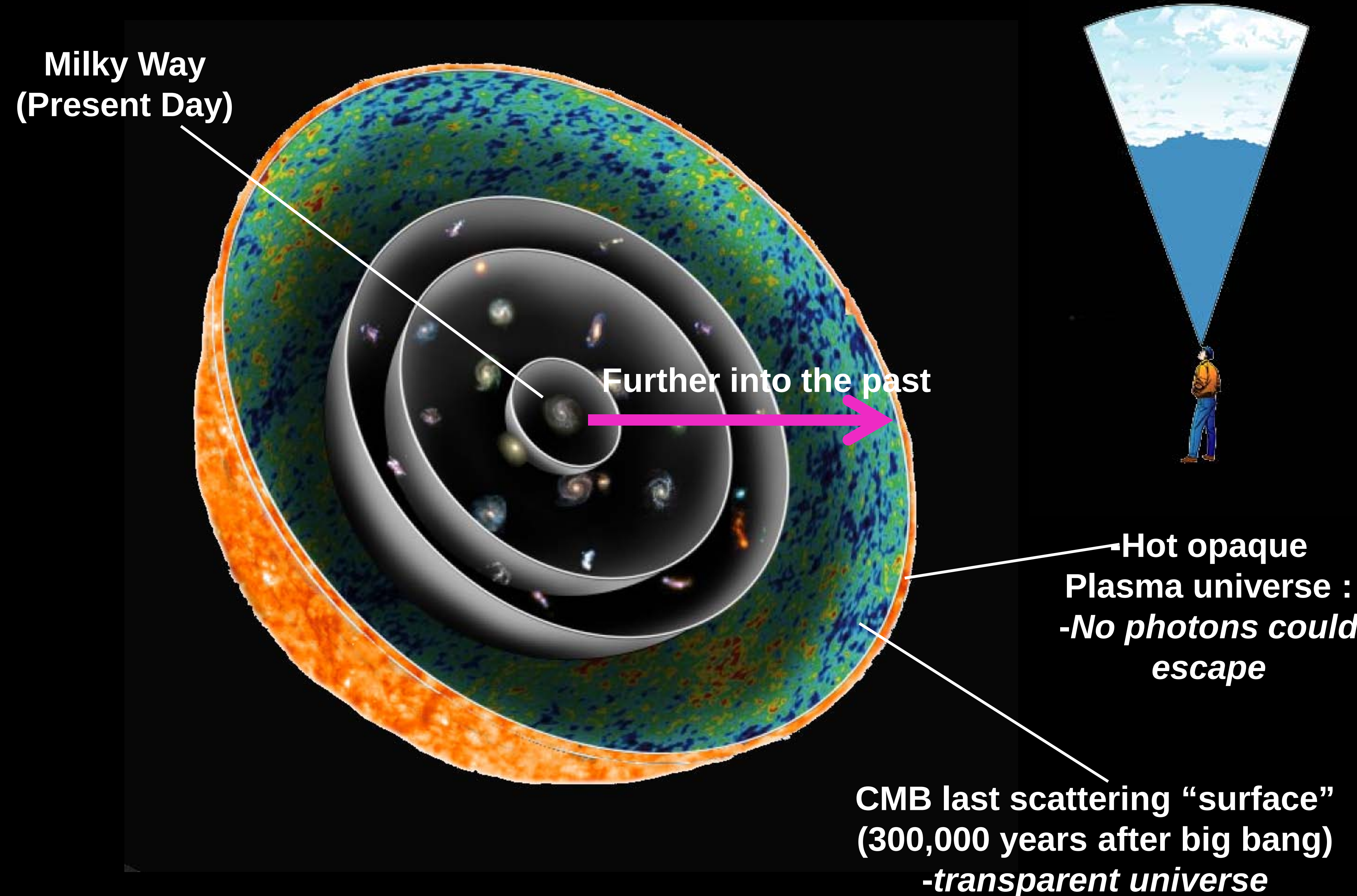
Cosmic Microwave Background Radiation



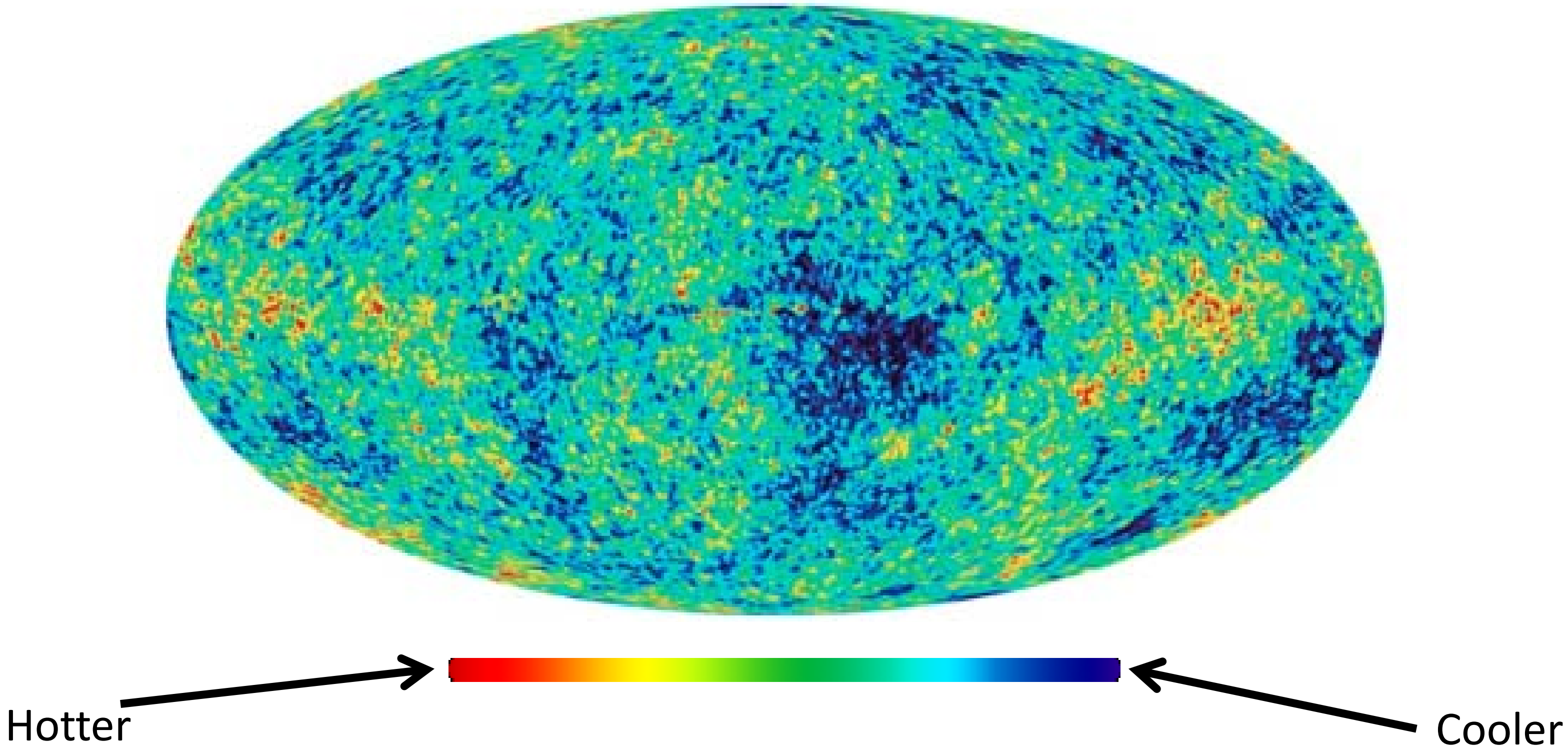


[1] http://abyss.uoregon.edu/~js/21 ... e Together" by Nancy Atkinson

Cosmic Microwave Background Radiation



CMB Temperature Variation map

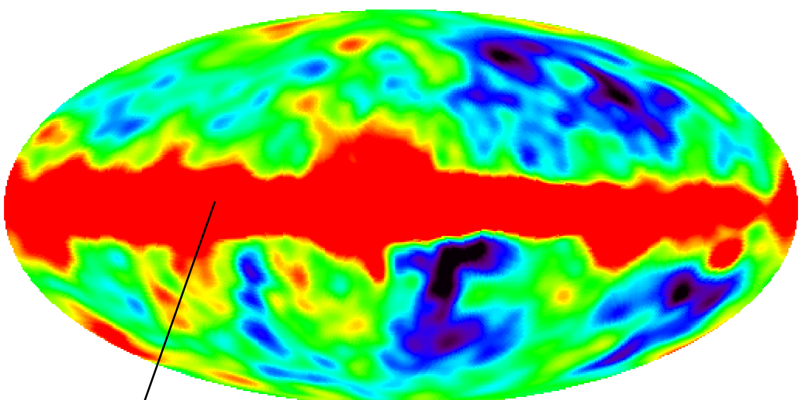


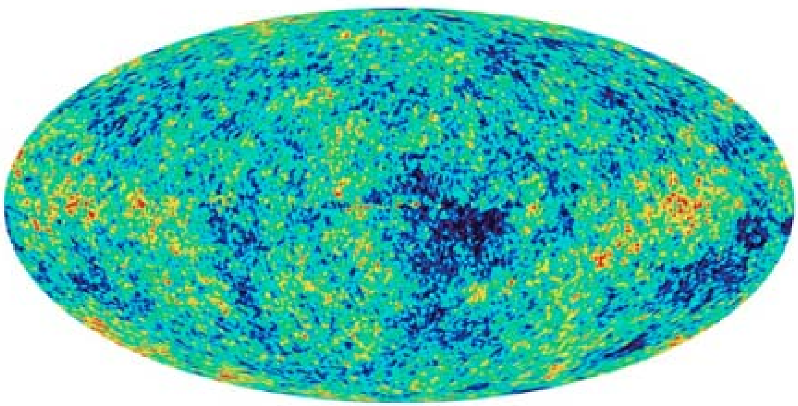
Mapping CMB variations can answer:

- How did the universe *begin,* and how will it *end*?
- how old is the universe?
- what is it made of? (dark matter/energy?)
- how did galaxies and other large structures form?

LATTE Big Picture:

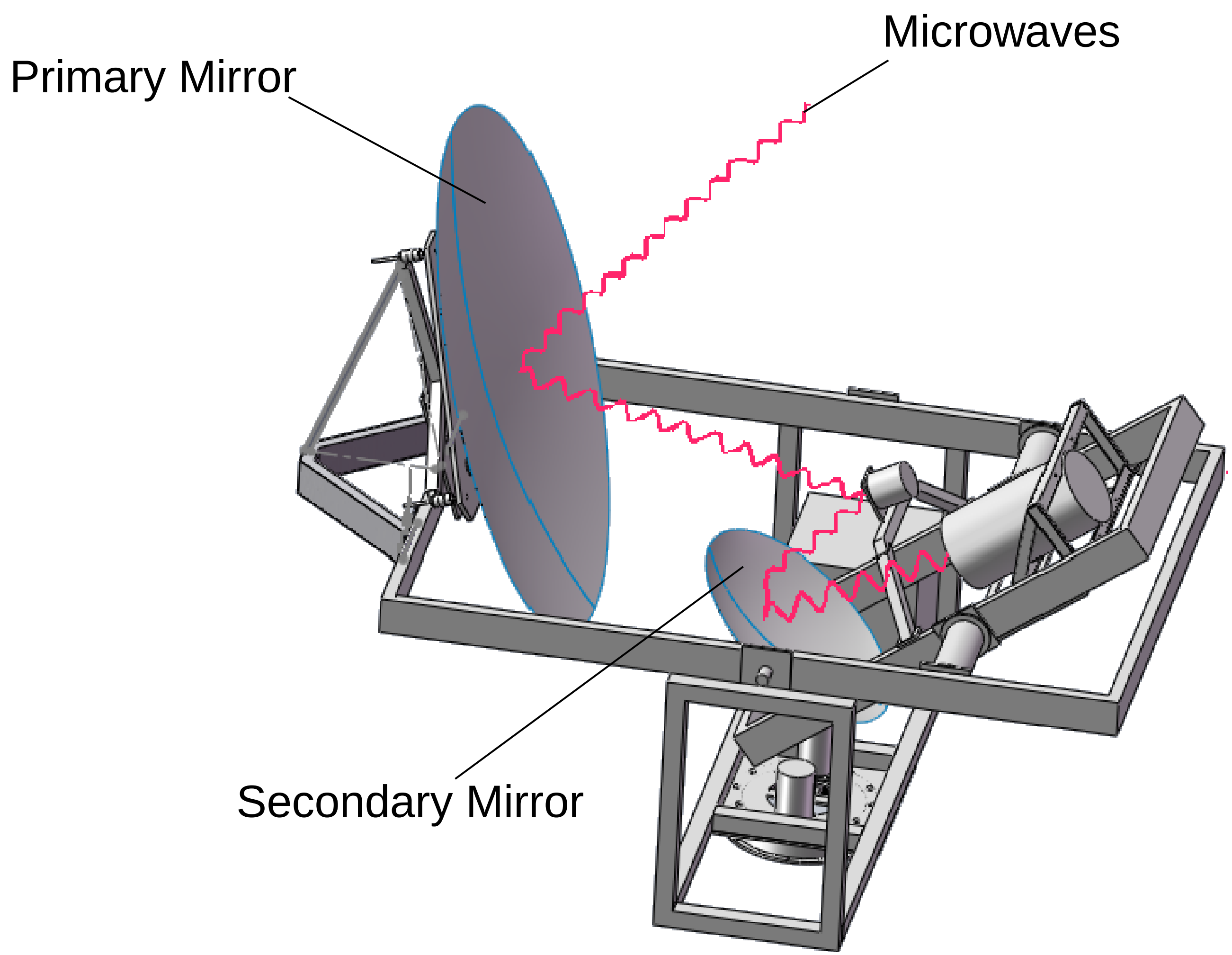
To understand microwave emissions from the Milky Way galaxy in order to fully subtract them from the CMB.



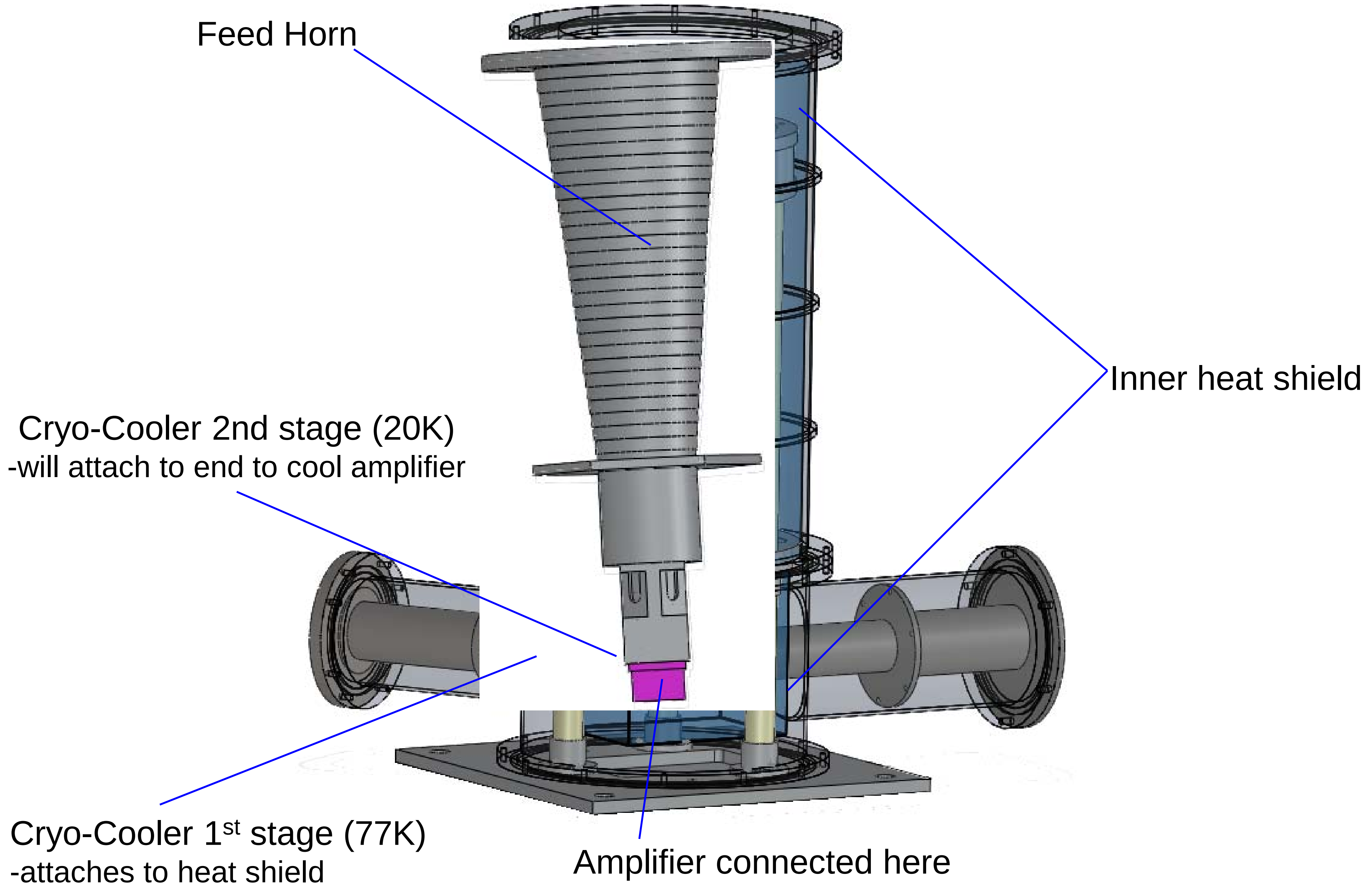


Radiation from plane of Milky Way Galaxy

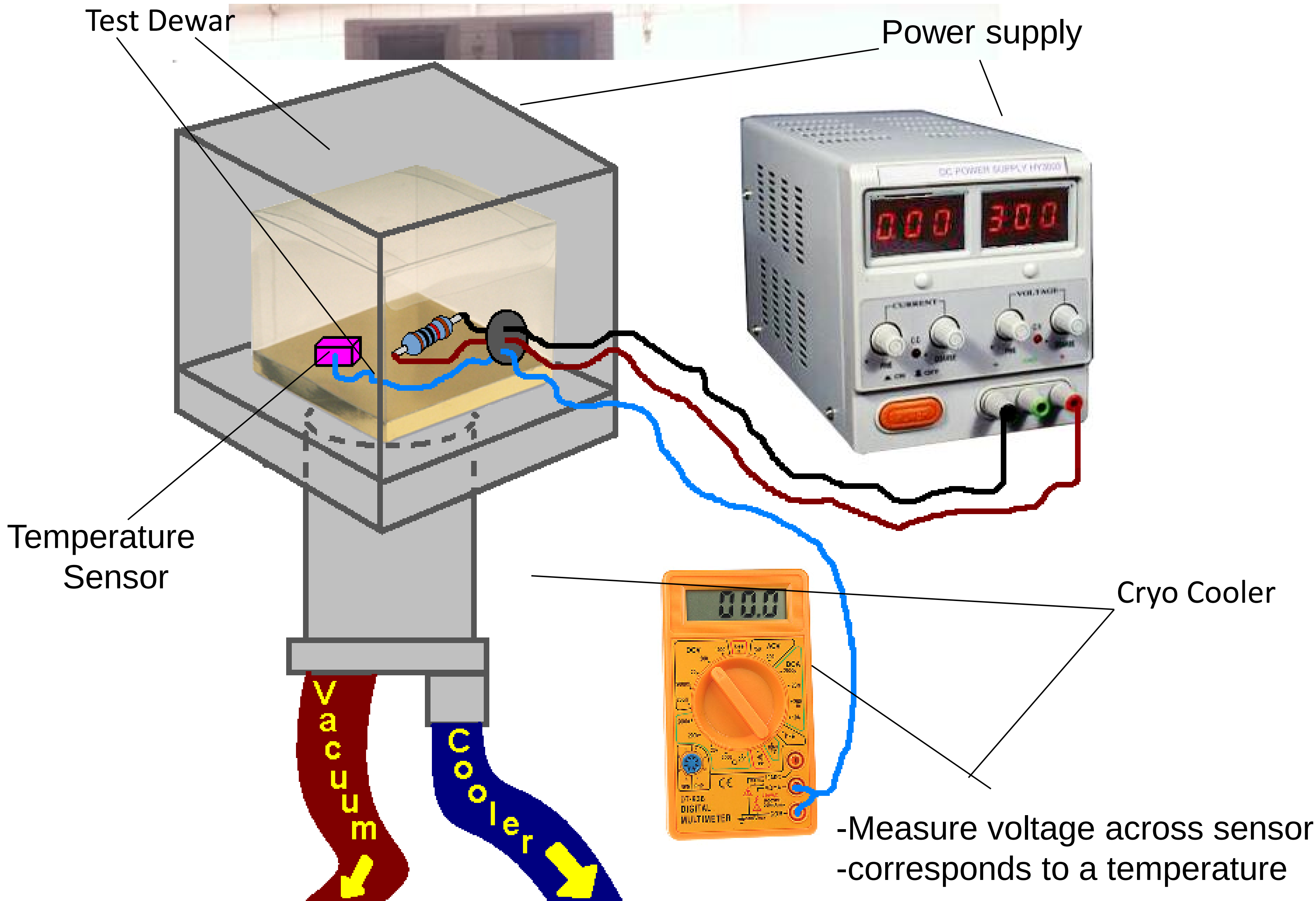
Main Goal for LATTE: Microwave Telescope



Summer Goal: Dewar

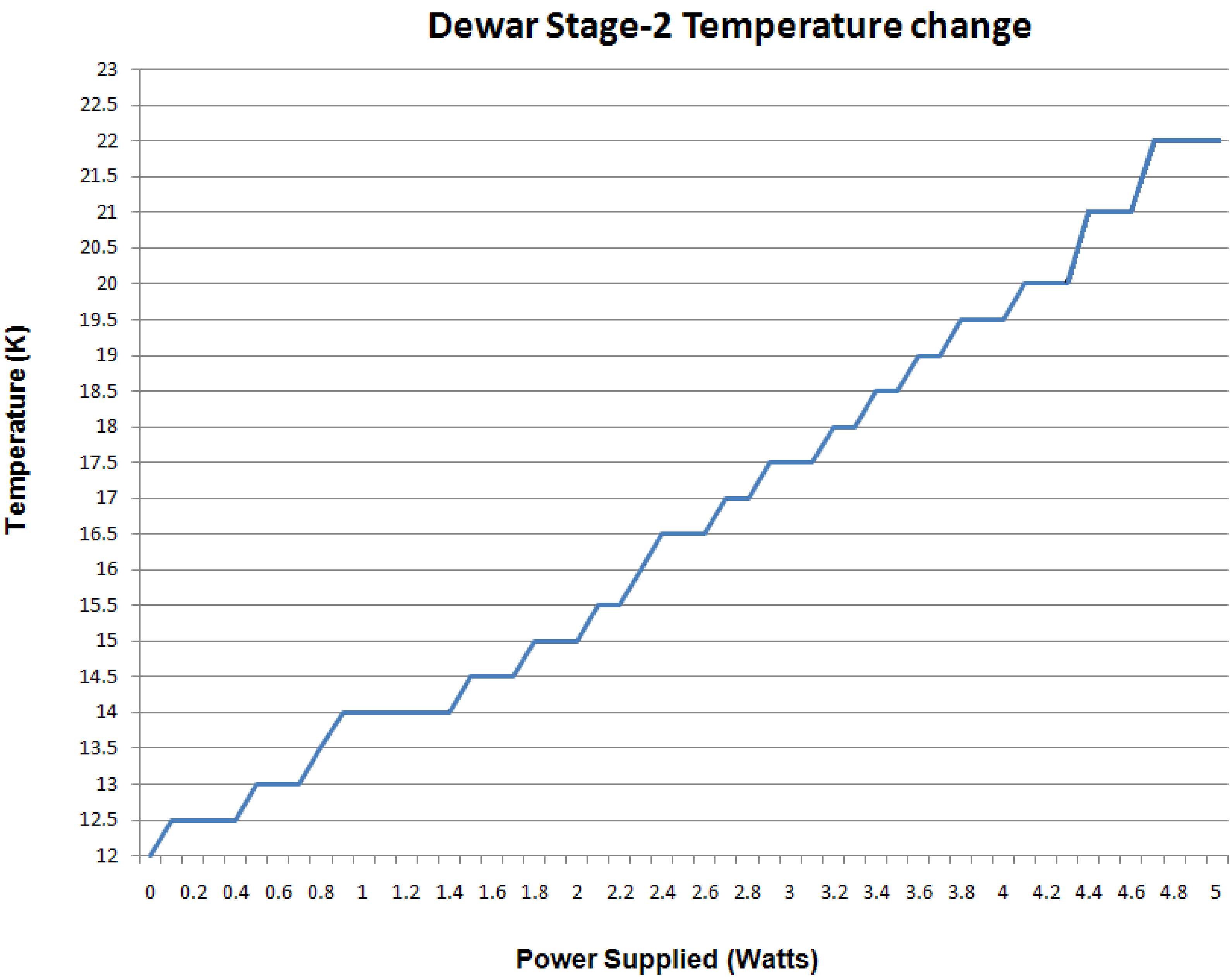


Test Dewar

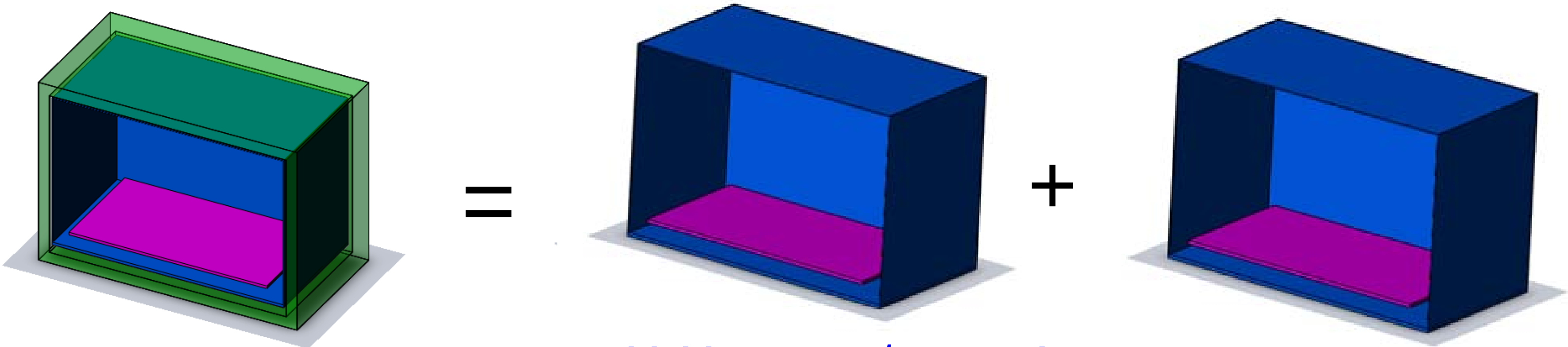


Test Dewar
Power supply
Temperature Sensor
Cryo Cooler
Vacuum
Cooler
-Measure voltage across sensor
-corresponds to a temperature

Internal Temperature Change Data



Heat transfer calculation for Dewar surfaces:



“Whole test dewar” = ***“Outer 300K shield & 77K shield”*** + ***“77K shield & 20K 2nd stage plate”***

“77K shield & 20K 2nd stage plate”

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

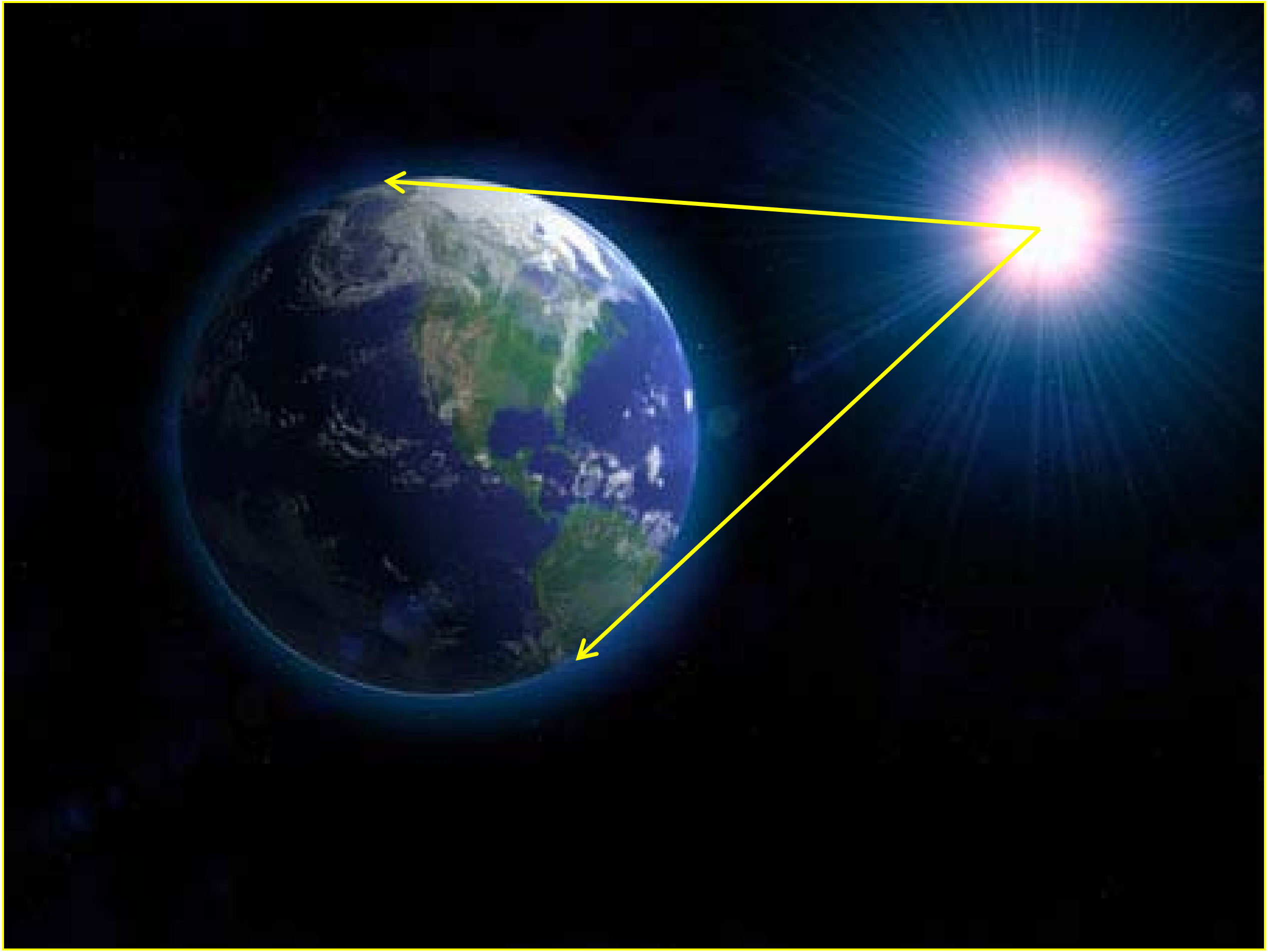
“Heat transfer summation equation for 6 surfaces”

- j and k represent surfaces that emit and absorb heat (respectively.)
- The goal was to solve for q_j $(j = 1, 2, 3, 4, 5, 6)$; the net heat radiation flux going through each unique face of the Dewar from all the other faces.
- Except for F_{kj}, all other variables in the equations were known.
- We had to solve for all F_{kj} values first, aka ***“view factors”***
- A ***view factor*** is the fraction of the total heat radiation leaving surface k that is intercepted by surface j.

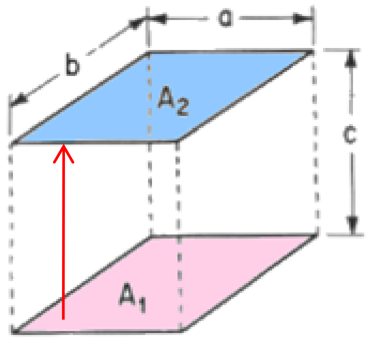
View factor from the Sun to the Earth:

$$F_{sun-earth}$$

-The fraction of the total radiated energy from the sun that hits the Earth's surface.



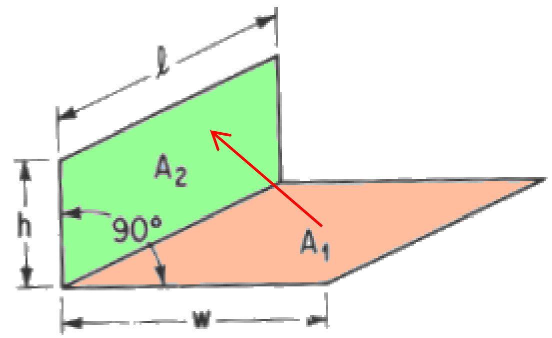
Examples of View Factor Calculations for the Test Dewar (flux from 77K shield to 2^{nd} stage)



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

```
a = .13981;
b = .26194;
c = .26194;
X = a/c;
Y = b/c;
```

➡ $F_{12} = 0.123445$



$$F_{1-2} = \frac{1}{W\pi}\left(W\tan^{-1}\frac{1}{W} + H\tan^{-1}\frac{1}{H} - \sqrt{H^2+W^2}\tan^{-1}\sqrt{\frac{1}{H^2+W^2}} + \frac{1}{4}\ln\left\{\frac{(1+W^2)(1+H^2)}{1+W^2+H^2}\left[\frac{W^2(1+W^2+H^2)}{(1+W^2)(W^2+H^2)}\right]^{W^2}\left[\frac{H^2(1+H^2+W^2)}{(1+H^2)(H^2+W^2)}\right]^{H^2}\right\}\right)$$

```
h = .13981;
l = .26194;
w = .26194;
H = h/l;
W = w/l;
```

➡ $F_{12} = 0.15165$

36 view factors!

$$F_{1,1} = F_{2,2} = F_{3,3} = F_{4,4} = F_{5,5} = F_{6,6} = 0$$

$$F_{1,2} = A$$

$$F_{2,1} = \frac{A_1}{A_2} * F_{1,2}$$

$$F_{5,3} = F_{6,4} = F_{4,6} = F_{3,5} = B$$

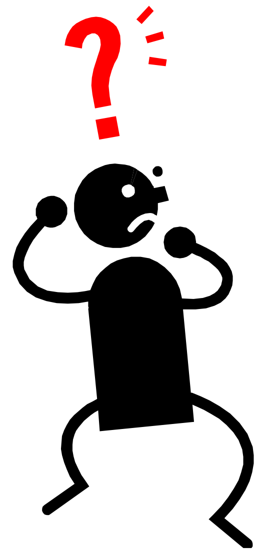
$$F_{1,3} = F_{1,4} = F_{1,5} = F_{1,6} = AA$$

$$F_{3,1} = F_{4,1} = F_{5,1} = F_{6,1} = \frac{A_1}{A_3} * F_{1,6}$$

$$F_{2,3} = F_{2,4} = F_{2,5} = F_{2,6} = BB$$

$$F_{3,2} = F_{4,2} = F_{5,2} = F_{6,2} = \frac{A_2}{A_3} * BB$$

$$F_{4,3} = F_{5,4} = F_{6,5} = F_{5,6} = F_{4,5} = F_{3,4} = F_{3,6} = F_{6,3} = AAA$$

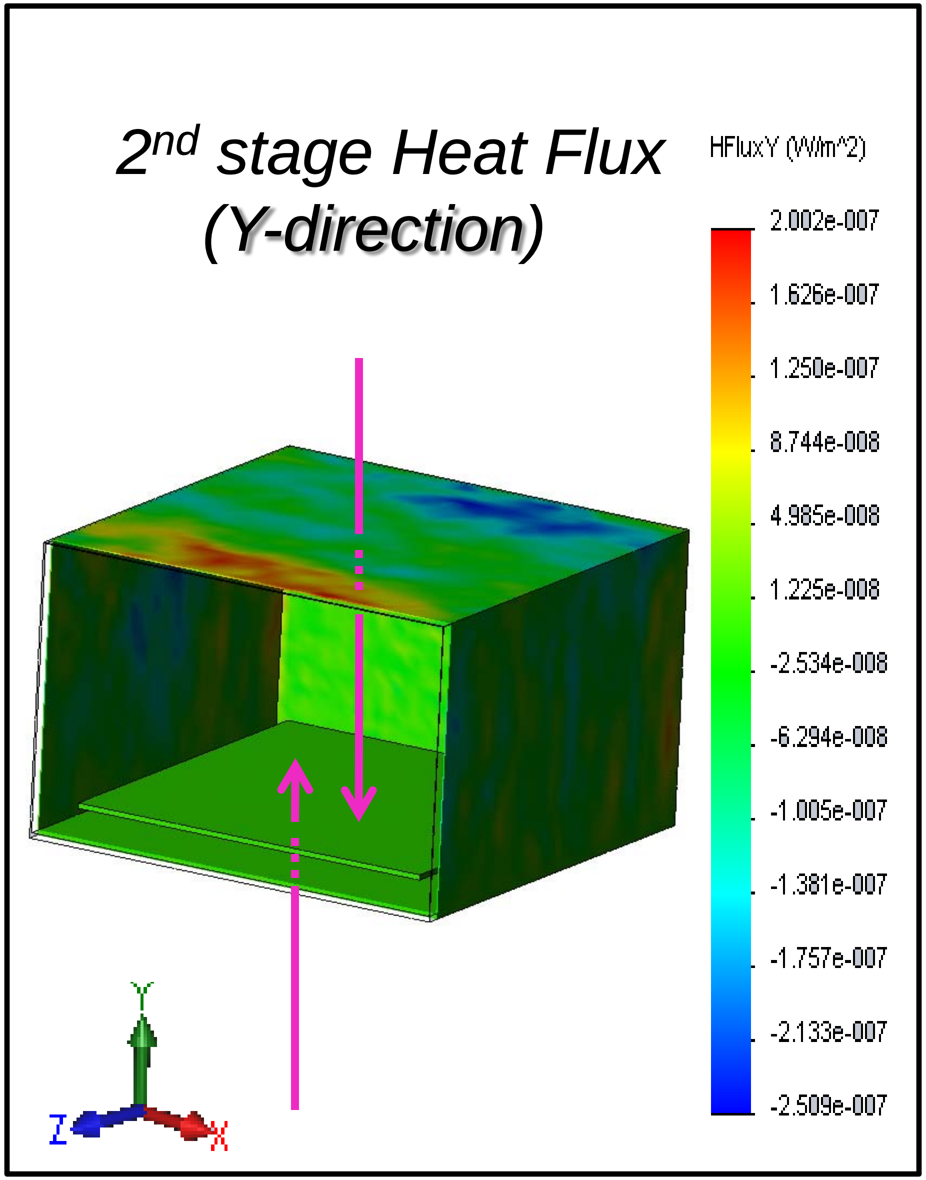


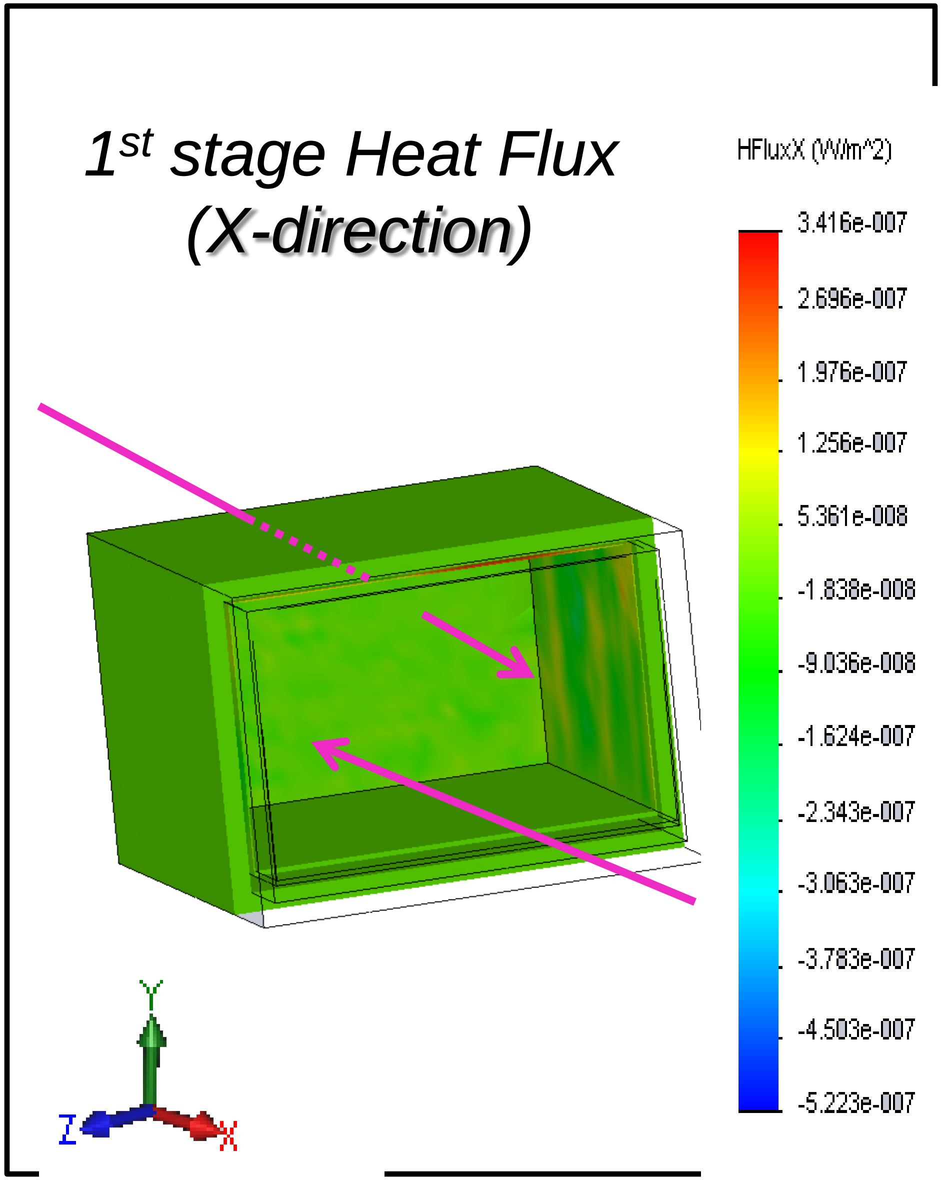
$$\sum_{k=1}^{6}\sum_{j=1}^{6}\left(\frac{\delta_{kj}}{\varepsilon_j} - F_{kj}\right) * q_j = \sum_{k=1}^{6}\sum_{j=1}^{6}\left(\delta_{kj} - F_{kj}\right) * \sigma T_j^{\,4}$$

Final Heat Flux Answer:

Net Heat Flux = -0.002734 watts of heat through the second stage of the Dewar!

Radiative heat transfer simulation attempts (SolidWorks)

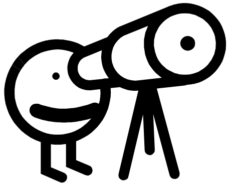




Future Goals

•finish experiment with test dewar and fix simulations so that I can compare all three of my heat flux results for any surface I want

•If theoretical predictions match experimental data, then I will do heat transfer calculations and simulations for our real dewar design for the microwave telescope

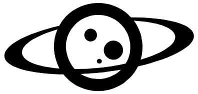


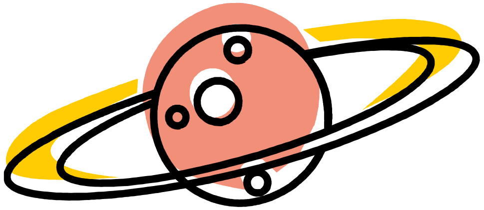
Summary

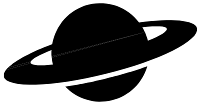
•Mapping the **C**osmic **M**icrowave **B**ackground is necessary for us to truly understand the universe’s underlying physical processes, which will ultimately lead to technological advances in many areas of science and engineering.

•This means it is necessary to understand and filter out interfering Milky Way Galaxy foreground radiation from the CMB

•Accurate heat transfer predictions for the cryogenic system will help make future microwave telescope Dewar design more efficient, and reduce thermal noise in our data







Acknowledgements

I want to say **Thank you** SO MUCH to everyone who made this summer possible!