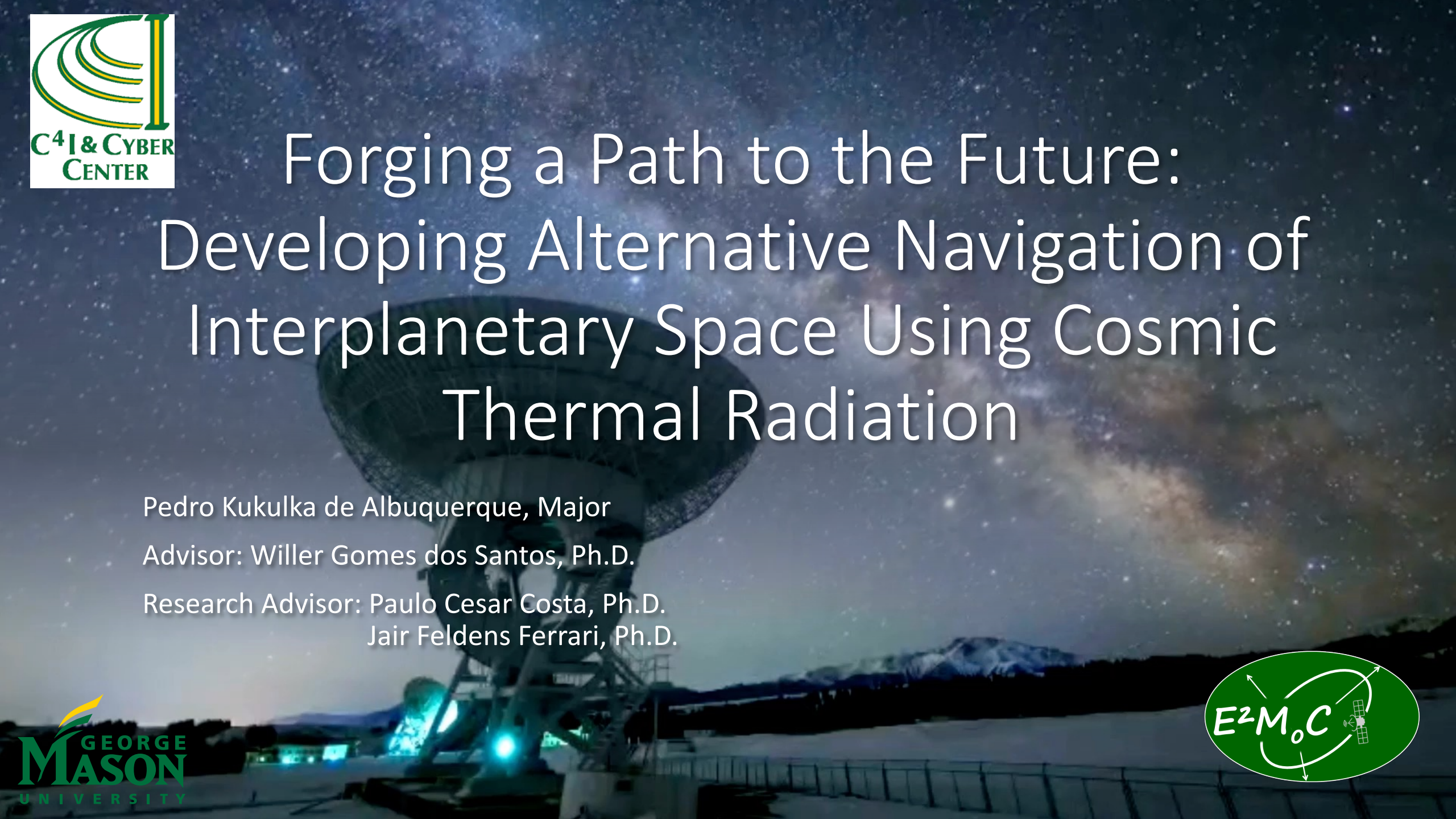
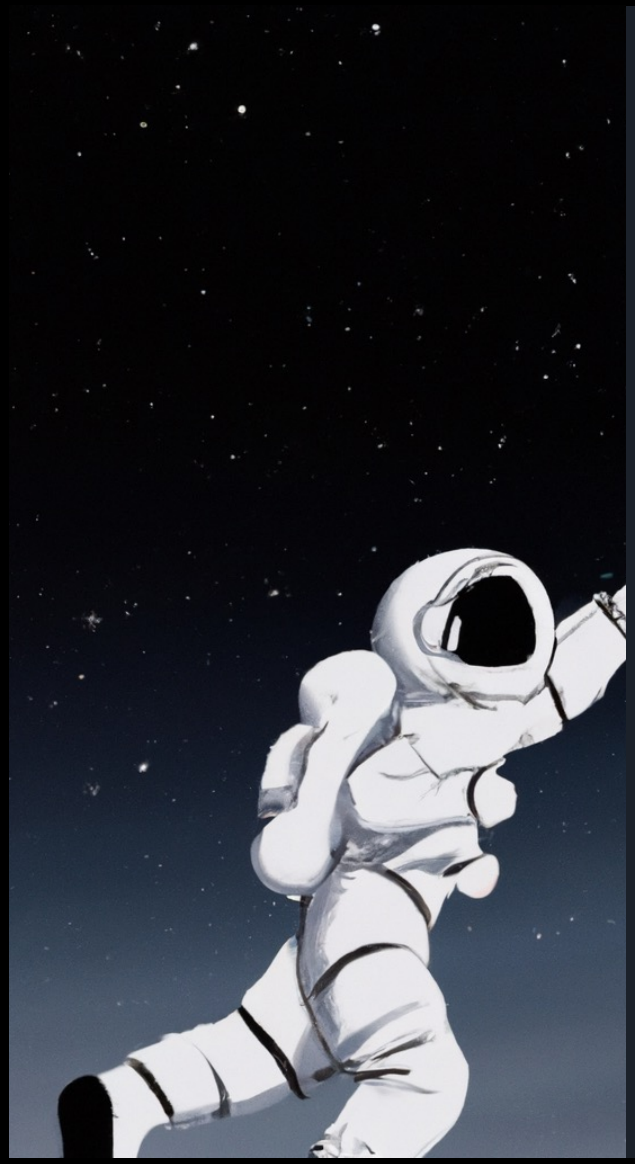


Forging a Path to the Future: Developing Alternative Navigation of Interplanetary Space Using Cosmic Thermal Radiation

Pedro Kukulka de Albuquerque, Major

Advisor: Willer Gomes dos Santos, Ph.D.

Research Advisor: Paulo Cesar Costa, Ph.D.
Jair Feldens Ferrari, Ph.D.



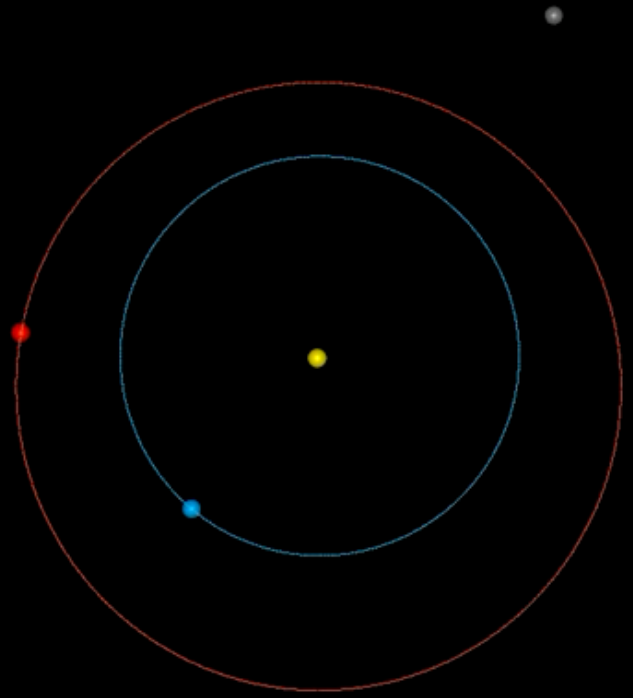
NAVIGATION

- A reference is needed for navigation to determine position and velocity
- SPACE: Everything is moving!
- Sensors: Mechanical, Electro-optical and RF
- Scenario change
- Ground -> Autonomous Systems

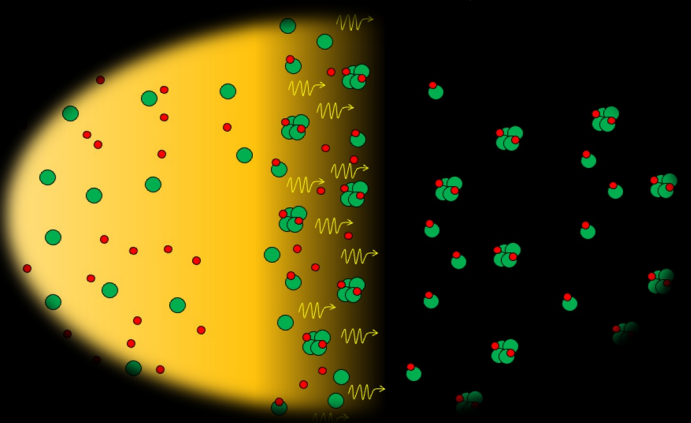
Challenges

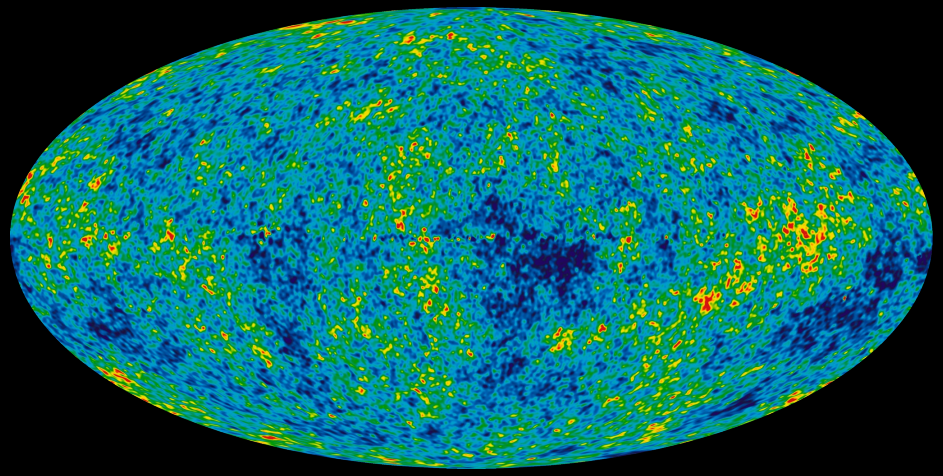
- Radiometric NAV:
  - Mission Safety
  - Scheduling Constraints
  - High Operational Costs
  - Operational limitations

- Autonomous NAV:
  - Optical / Pulsar
  - Integrated methodology
  - More navigation signals, better



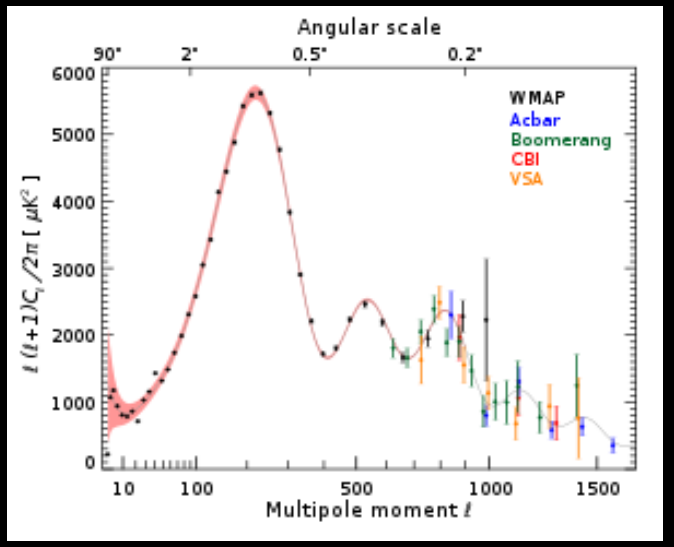
Cosmic Microwave Background

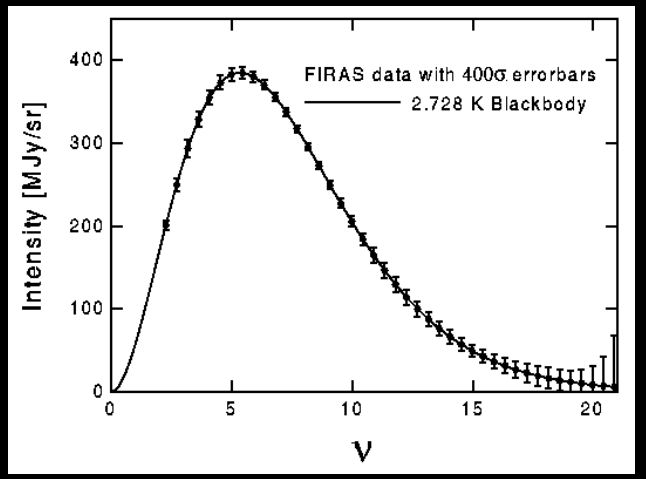




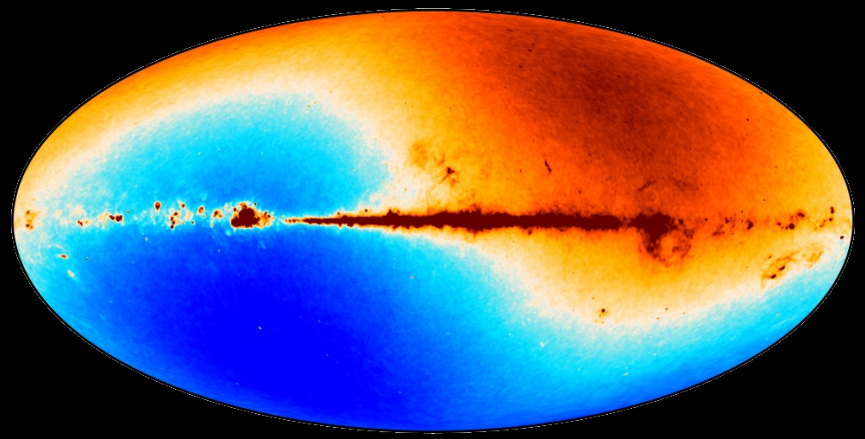
- Near Isotropic/Homogeneous
- Black Body Spectrum

- Anisotropies (1:100000)

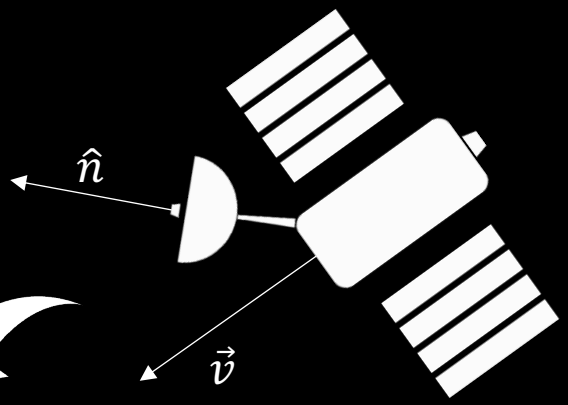




Dipole



$$T(\vec{v},\hat{n}) = T_0 \frac{\sqrt{1-\left|\frac{\vec{v}}{c}\right|^2}}{1-\vec{v}.\hat{n}}$$

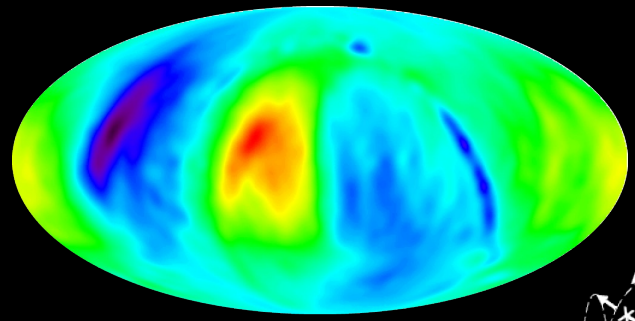


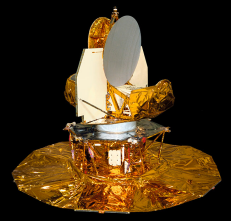
$$30Km/s \longrightarrow 100\mu K$$

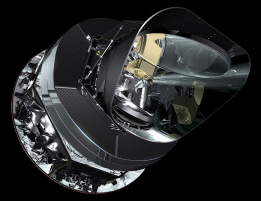
Measurement

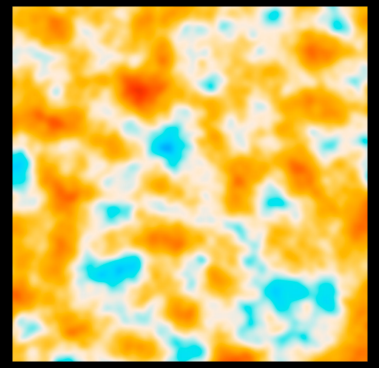
Sensitivity roughly doubling every 2.3 years!

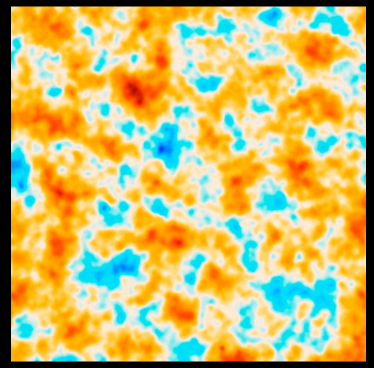
Systematic Errors





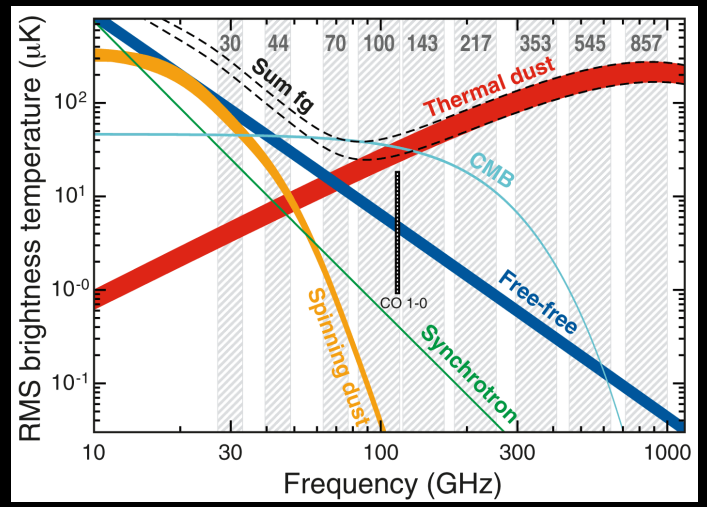




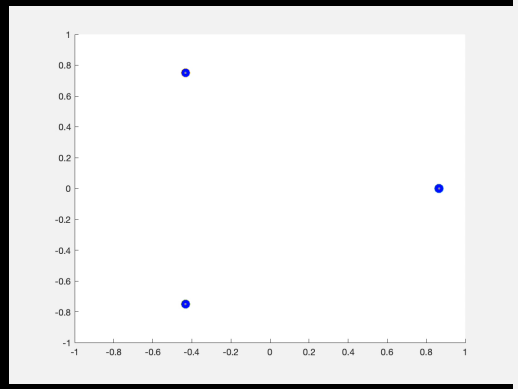


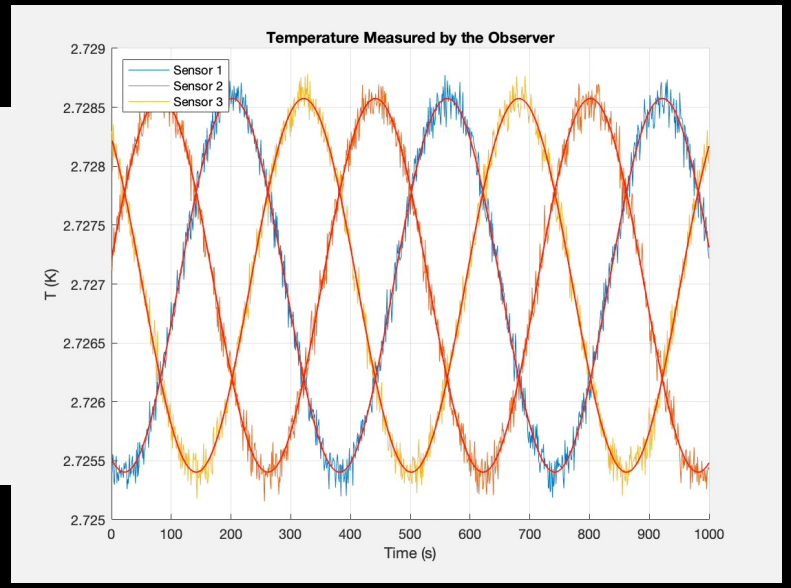
COBE WMAP Planck

Foreground Noise



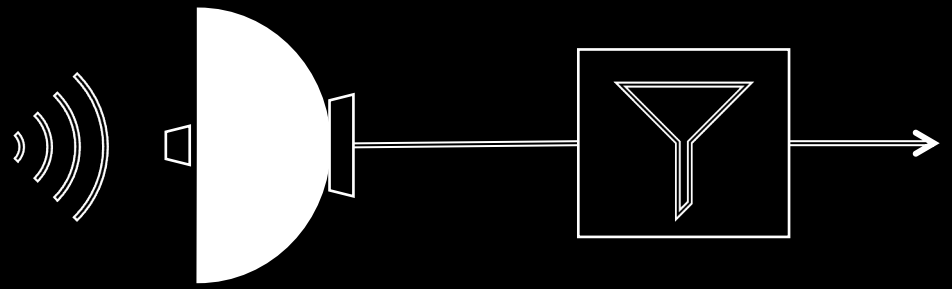
Navigating using CMB





Collecting

Filtering



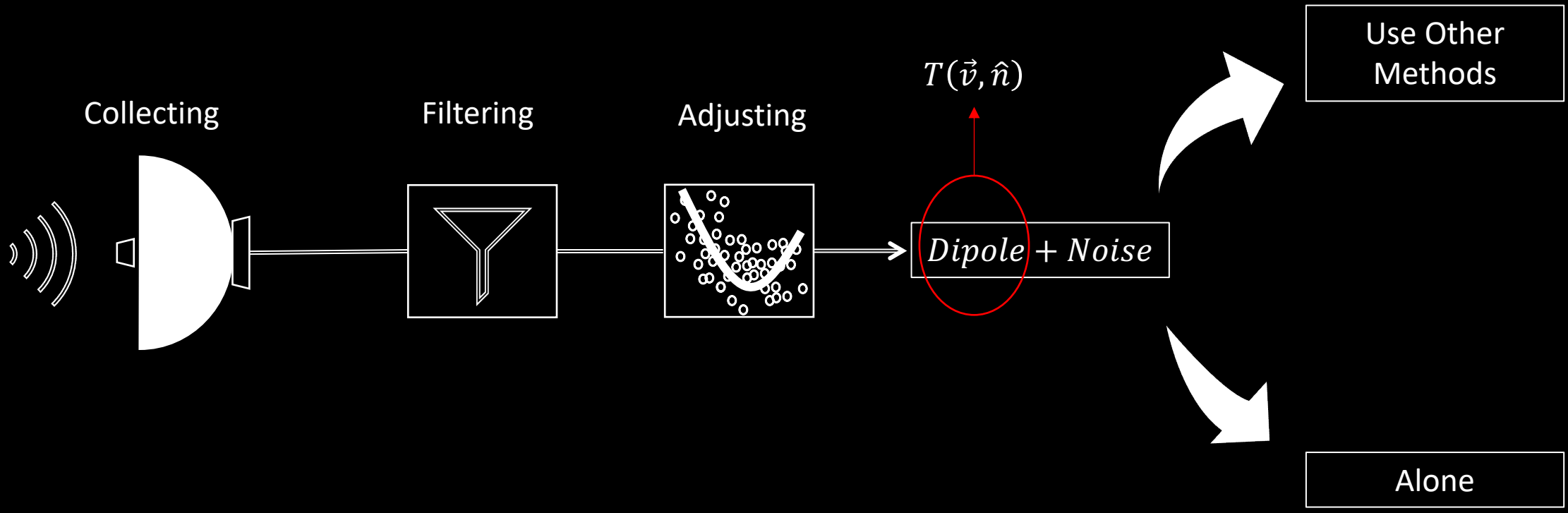
2.7255 ± 0.0006

$$CMB = T_0 + Dipole + Fluctuations + Noise$$

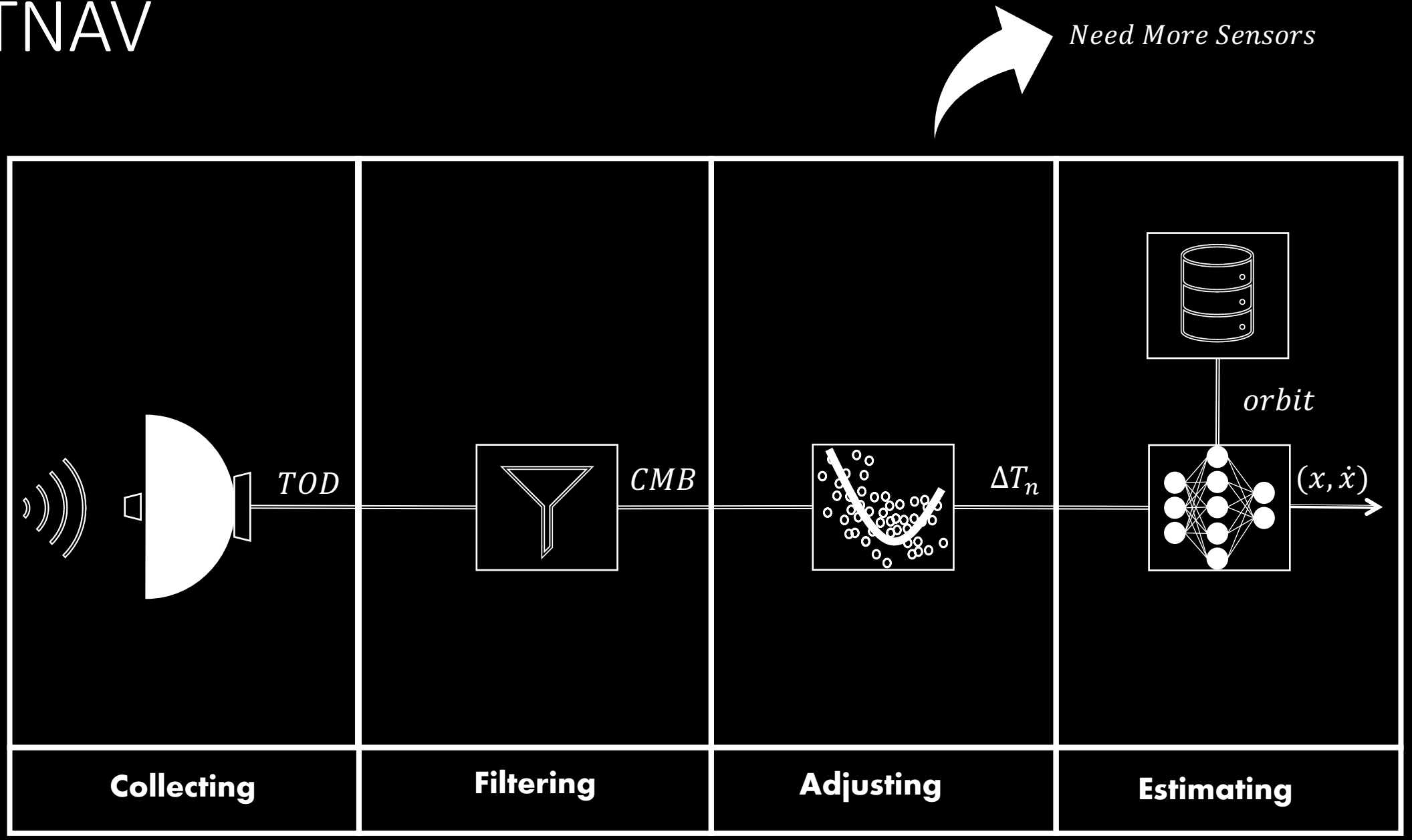
Almost Gaussian

$(0,100\mu K)$

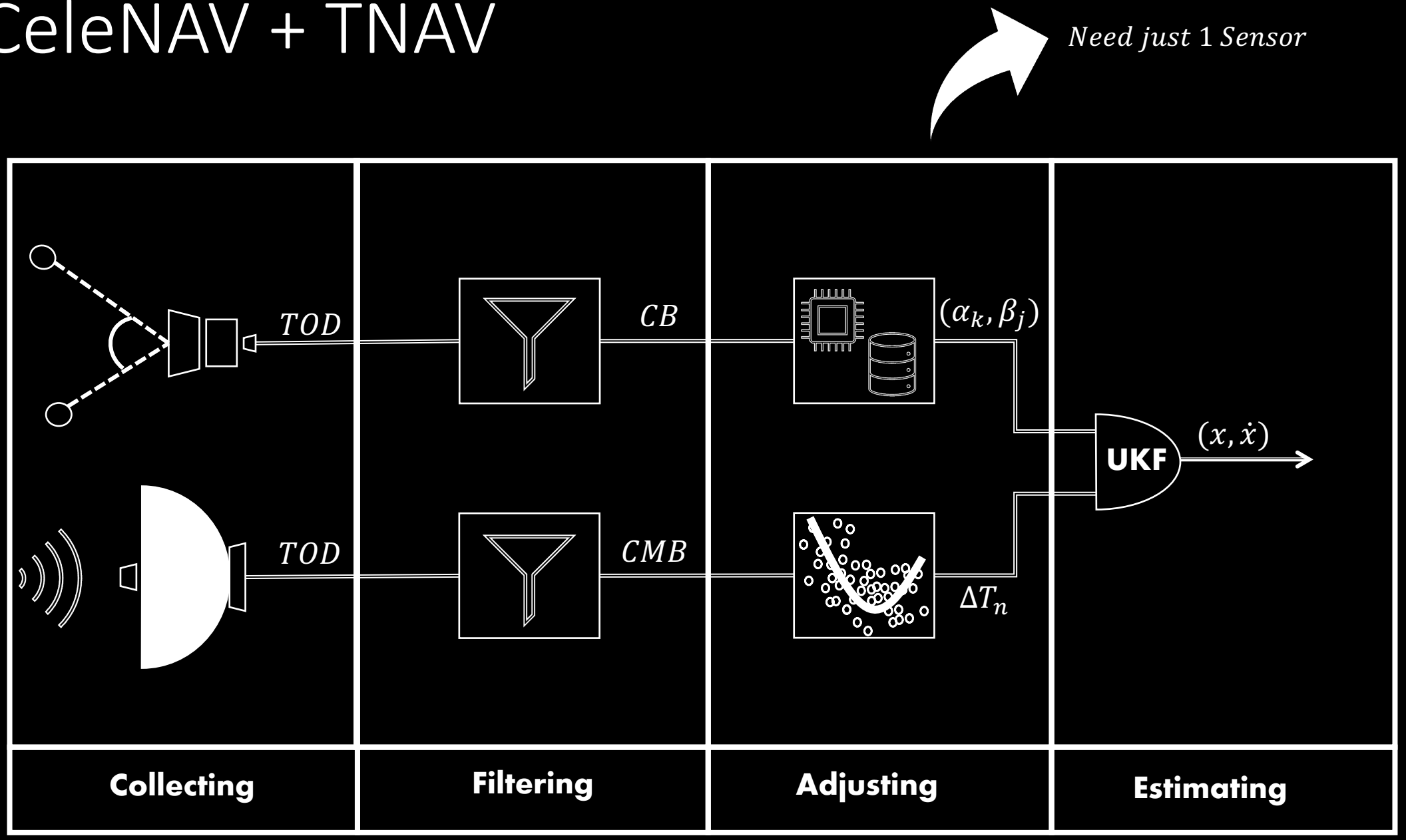
Navigating using CMB



TNAV


Need More Sensors
TOD
CMB
ΔT_n
orbit
$(x, \dot{x})$
Collecting
Filtering
Adjusting
Estimating

CeleNAV + TNAV



Final Considerations

- Space is a hostile place nowadays!
- The ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruption
- More sensors -> increase Resilience
- Technology?

Q&A

pkukulka@gmu.edu