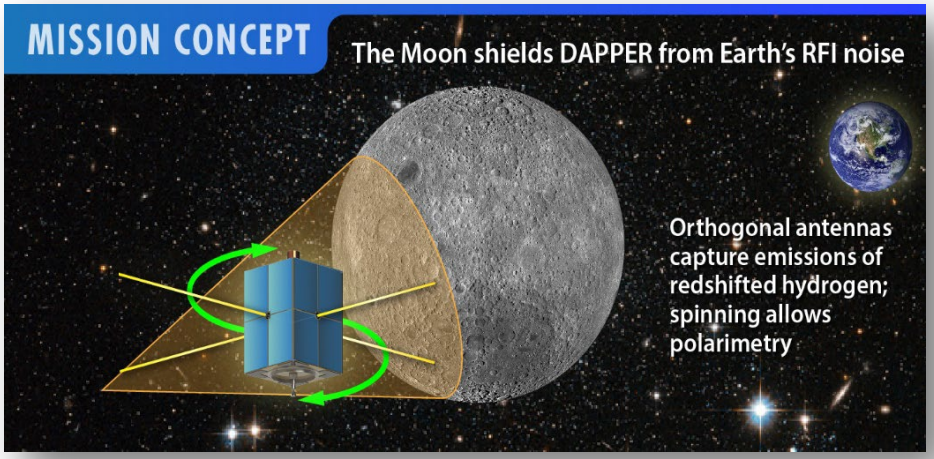
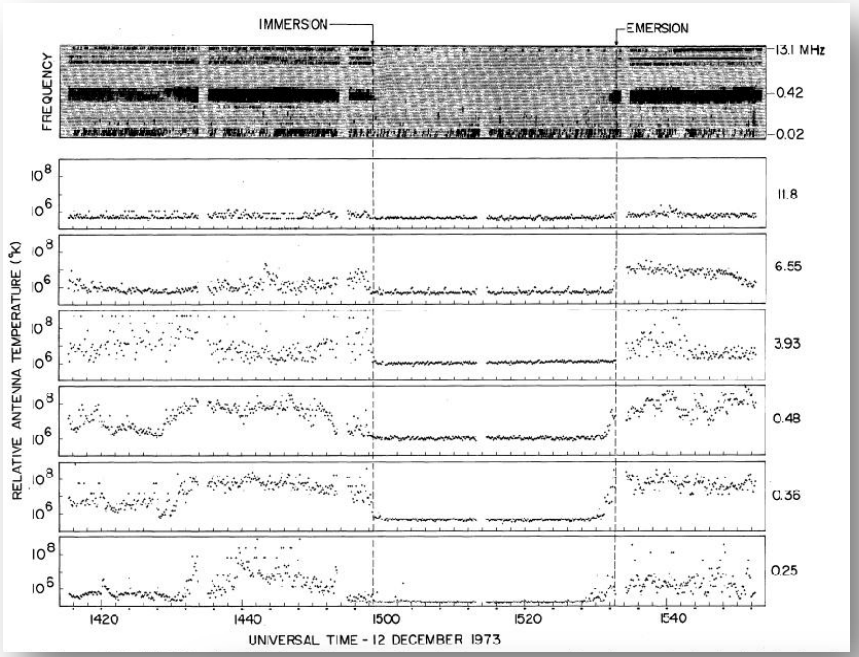
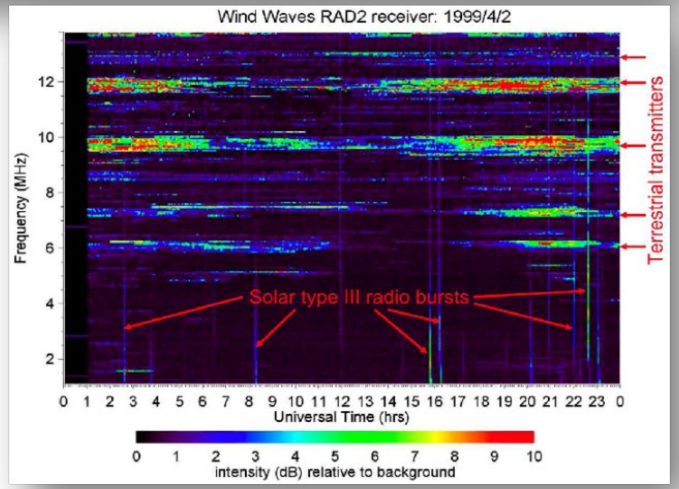
Lunar Farside: No RFI or Ionosphere!



RAE-2 1973





Wind/Waves data near the Moon

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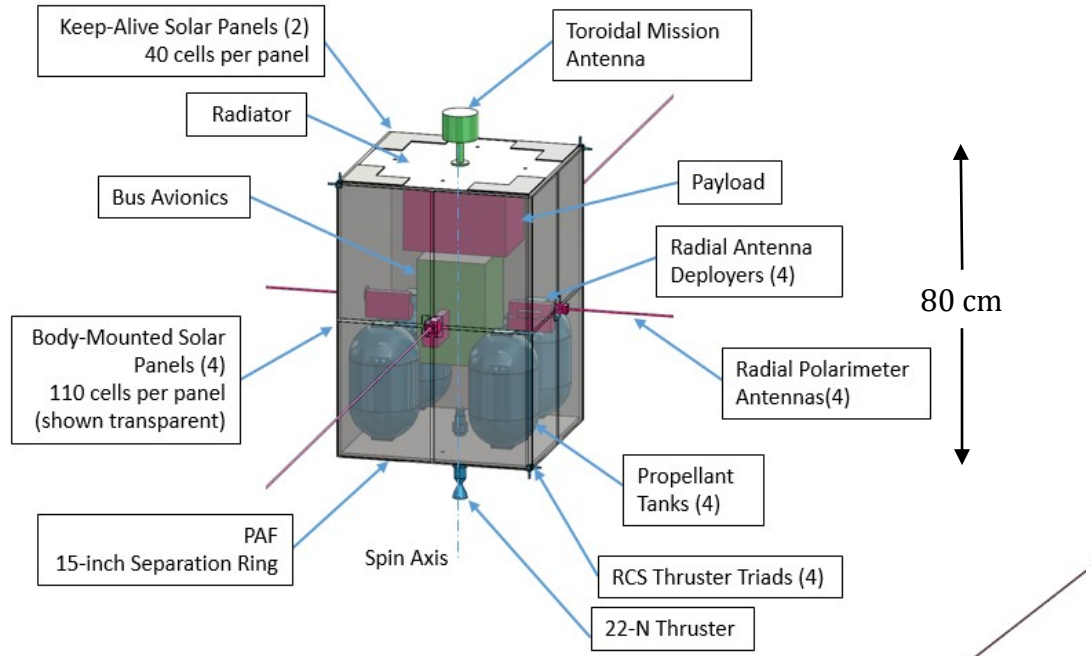
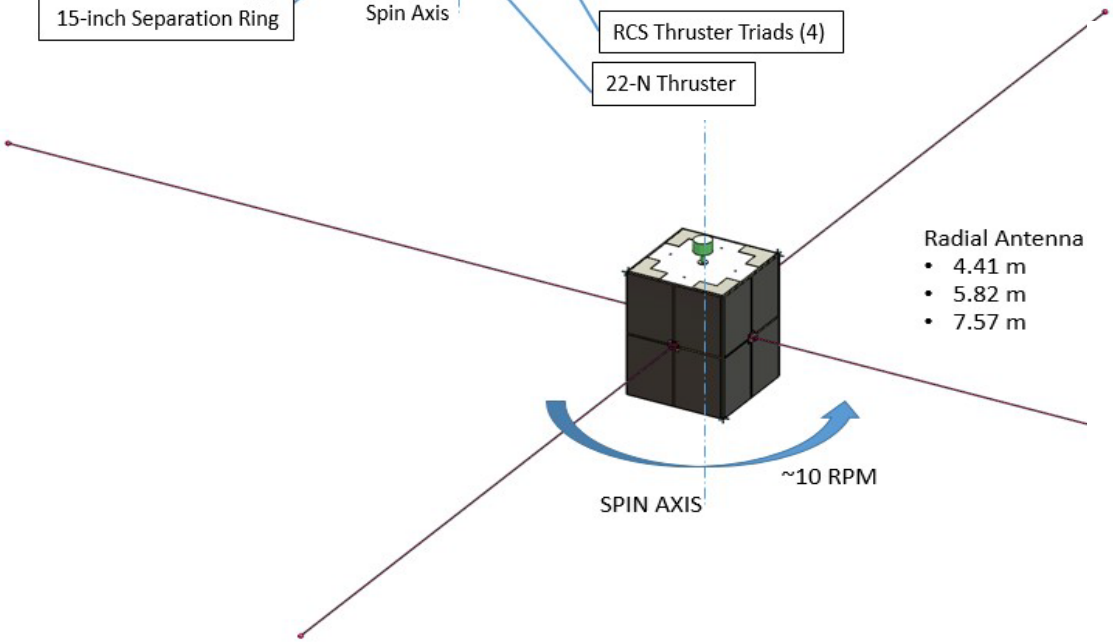
DARK COSMOLOGY:
INVESTIGATING DARK MATTER IN THE DARK AGES



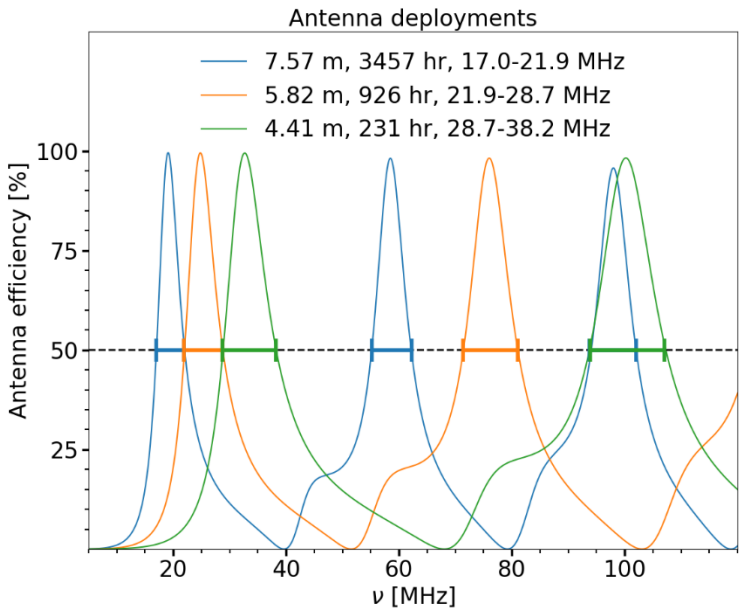


Spacecraft

- Deep Space Explorer bus by Bradford Space Industries.
- High impulse, high ΔV.

Antennas

- Deployable, spinning, wire boom antennas arranged in 2 orthogonal, co-linear pairs.
- 3 length deployments to "tune" instrument.



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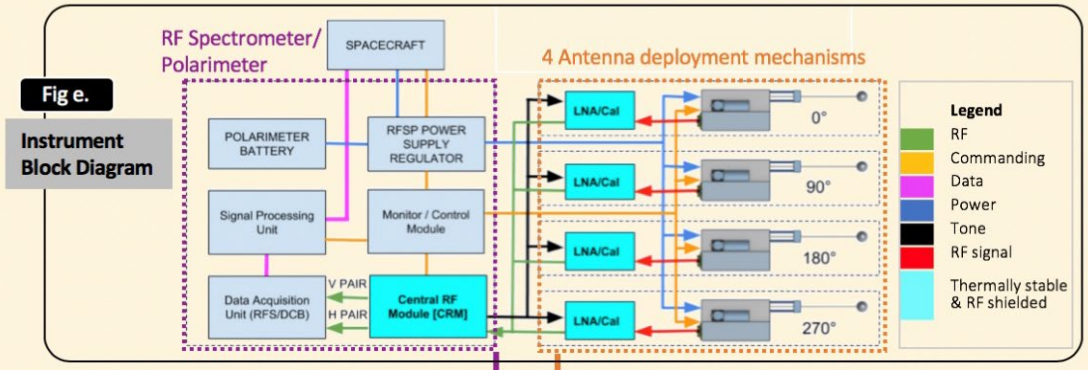
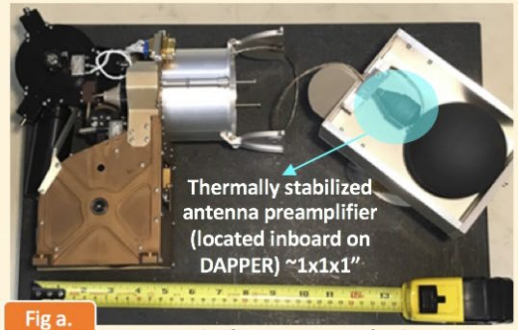
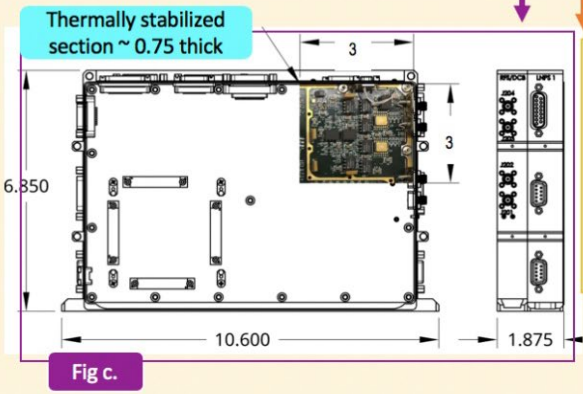


DAPPER Receiver heritage:
Parker Solar Probe/FIELDS Radio Frequency Spectrometer electronics board



DAPPER wire boom antenna heritage:
Van Allen Probe (RBSP) units
THEMIS/EFI spin plane boom system
• 20 successful deployments on orbit



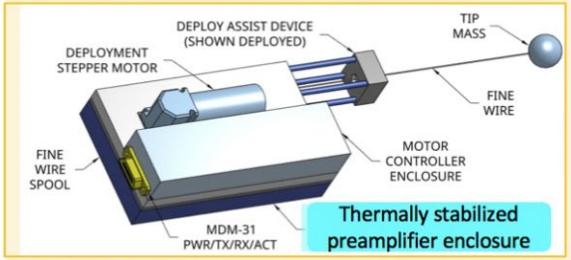


Fig d. **DAPPER monopole antenna:**
simplified version of heritage antenna, moving of preamplifier to S/C interior allows centralized thermal control

DAPPER Instrument

- High heritage from Parker Solar Probe, THEMIS, Van Allen Probes.
- Receiver gain variations:
  - Measured with high fidelity by frequency tones.
  - Controlled by stabilizing temperatures to $\pm 1°C$.
- Calibration:
  - Pre-launch lab measurements.
  - In-flight verification.
  - Fitting receiver characteristics using pattern recognition/MCMC pipeline.

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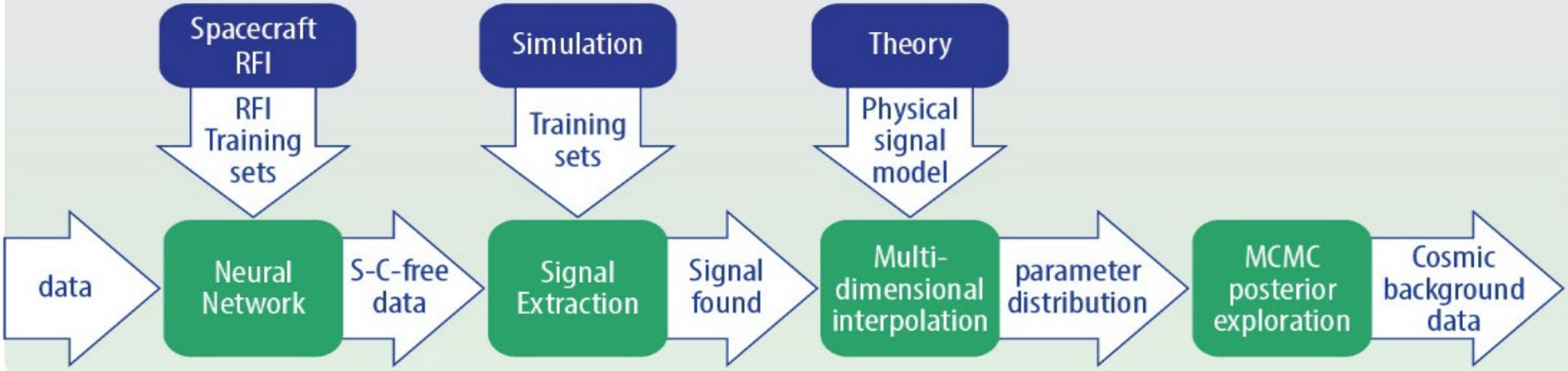
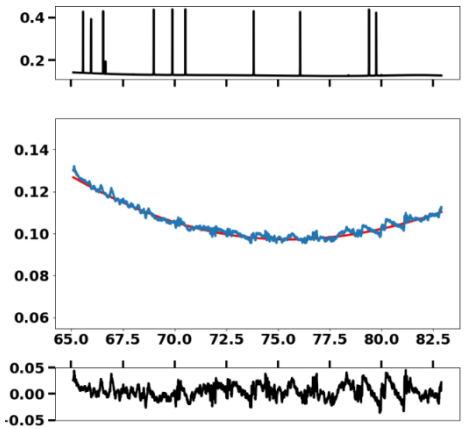
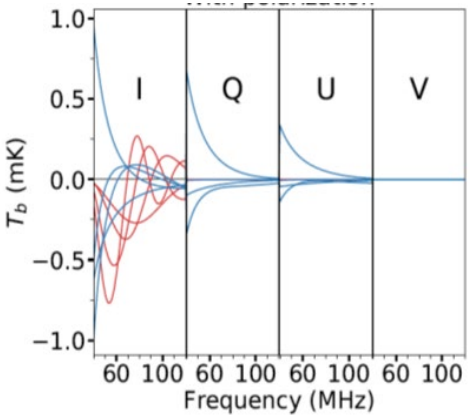
DATA PROCESSING PIPELINE

Pipeline uses pattern recognition and training sets to separate signal from known S/C, foreground, and systemic effects, and then fits cosmological models to the data.

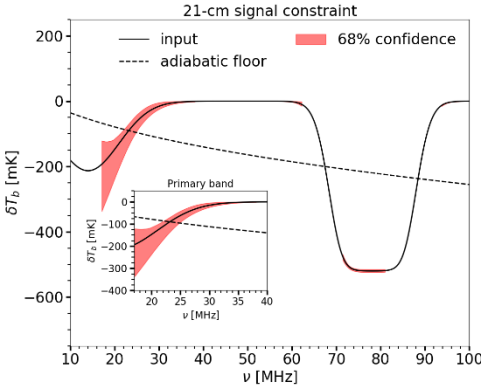




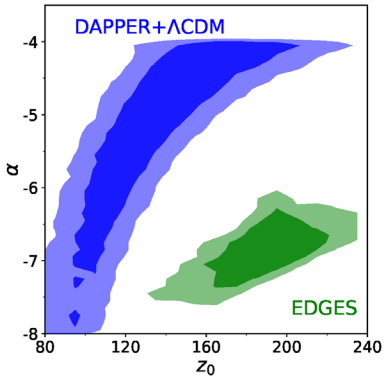
Removal of RFI using Kurtosis & Neural Network



Separate foreground from 21-cm signal using polarization & SVD



End-to-end simulation with sky + instrument systematics, signal models



DAPPER separates standard cosmology from added-cooling at >5σ

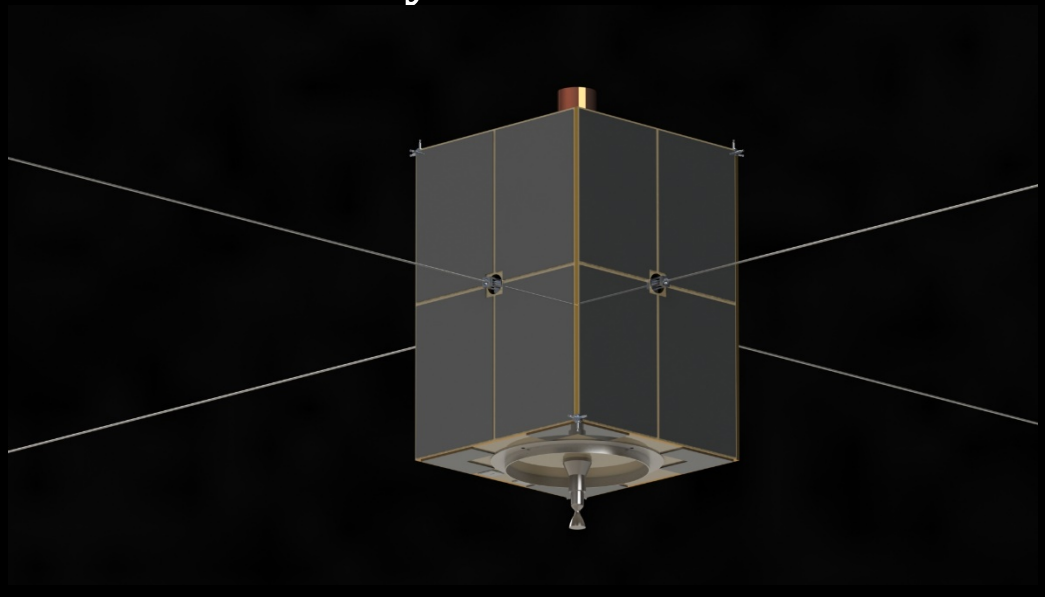
Summary

- The redshifted 21-cm Global Spectrum at $\lesssim$30 MHz offers the prospect of probing the nature & character of Dark Matter in the Dark Ages.
- These observations need to be conducted in space, in orbit of the Moon, to eliminate Earth ionospheric, RFI, & ground effects.
- Projection-induced polarization provides an independent measure of the galactic foreground.
- We developed a method which transforms the 21-cm signal extraction task from one where *absolute knowledge of system parameters* is required to one of *composing training sets where knowledge of the modes of variation* are used.
- DAPPER will differentiate between the standard cosmology model & added cooling models at >5σ level.

Burns, J.O., et al. 2019, "Dark Cosmology: Investigating Dark Matter & Exotic Physics in the Dark Ages using the Redshifted 21-cm Global Spectrum", Astro2020: Decadal Survey on Astronomy and Astrophysics, science white papers, no. 6; BAAS, Vol. 51, Issue 3, id. 6.

What's Next?

- DAPPER tied to Artemis program.
- Commence two-year instrument maturation to TRL 6.
- Work Plan
  - Mature RF spectrometer/polarimeter
  - Mature antenna system
  - Mature data analysis pipeline
- Schedule – launch in ~3-4 years.



Supplemental Slides

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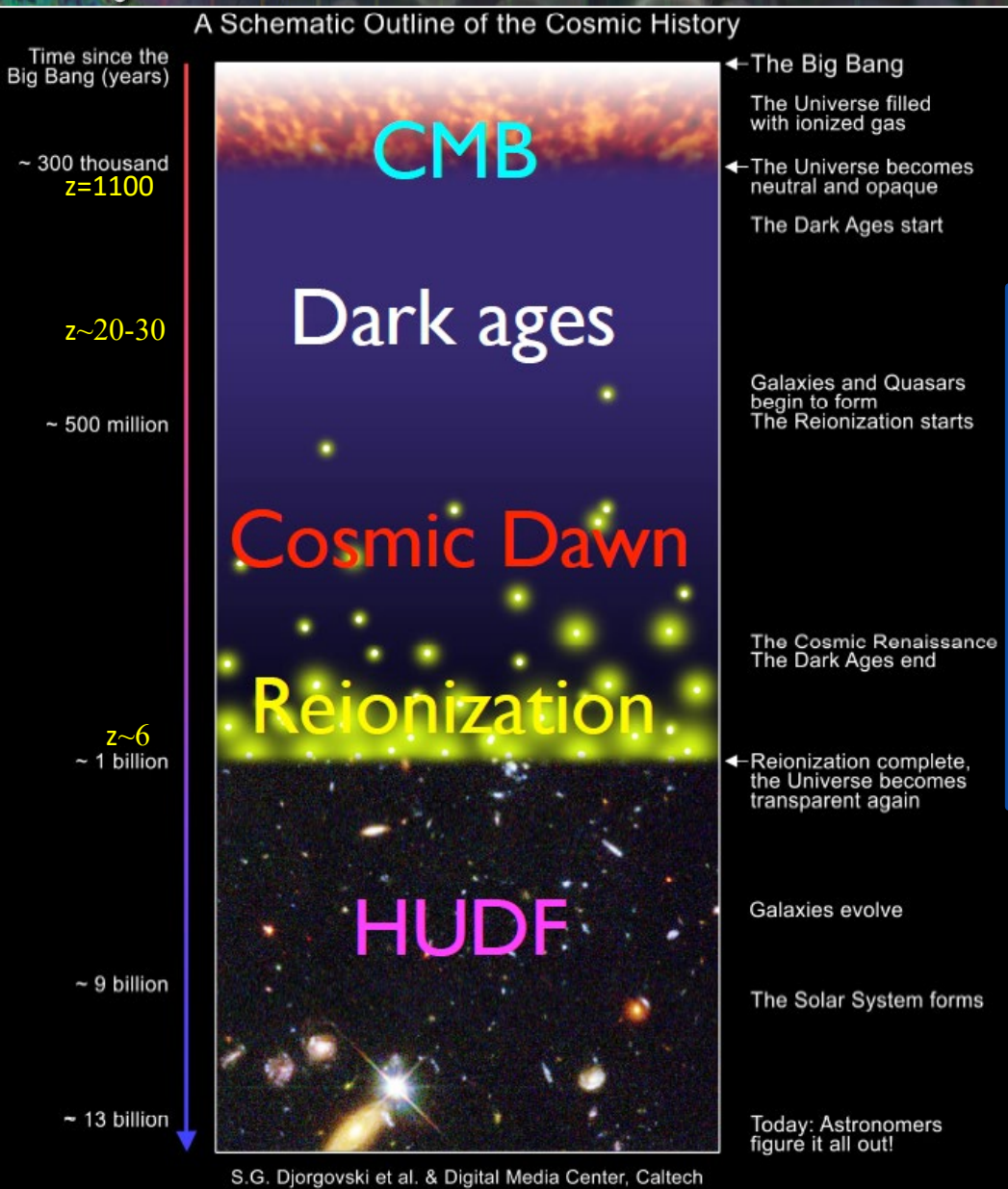

The First Stars

M. Norman, B. O'Shea et al.