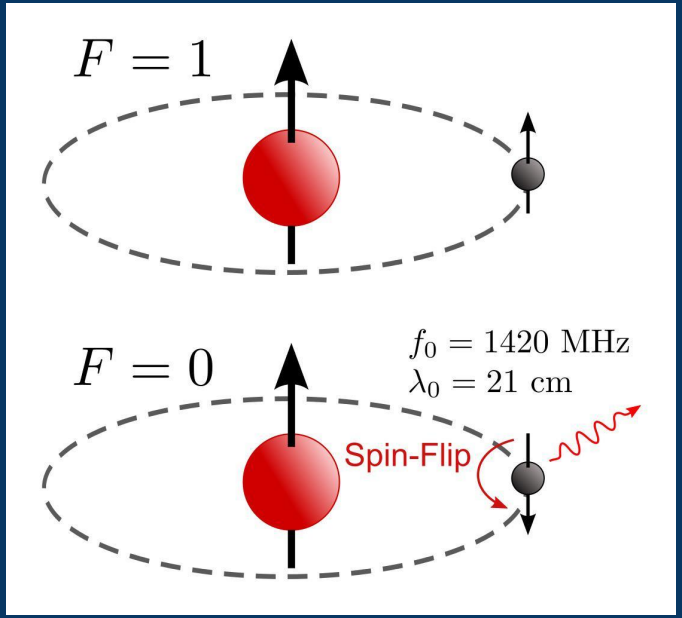
# A Brief Overview of 21-cm Cosmology

By Katherine Elder

# What is the 21-cm line?

- Hydrogen in the ground state
- Hyperfine transition caused by electron and nuclear spin states
- Parallel spin is higher energy
- “Forbidden” transition to lower energy state

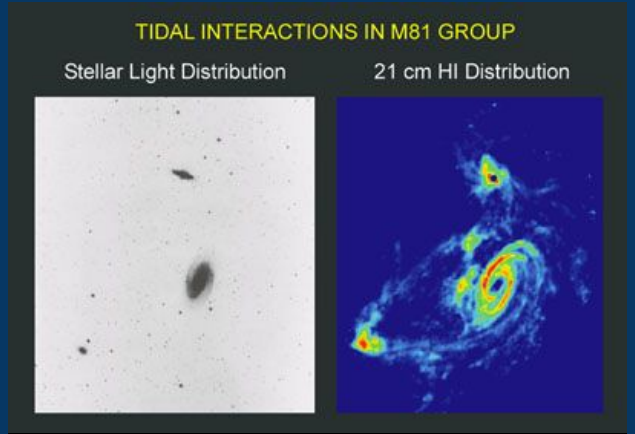


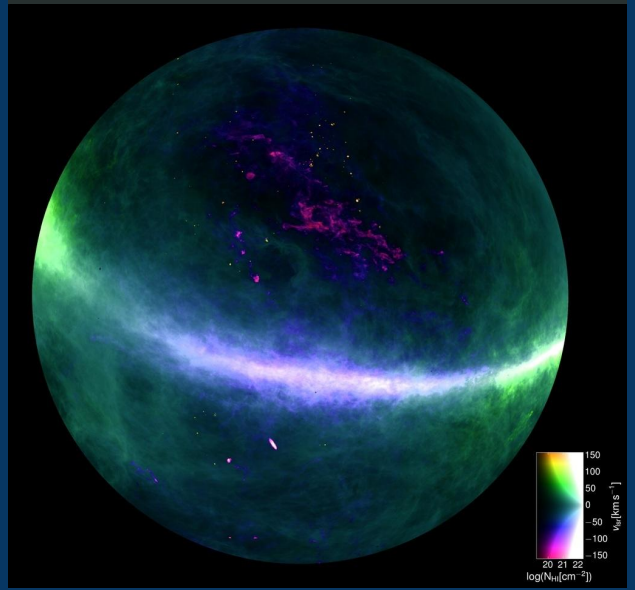
# First detection

- Theorized in 1944 by Hendrik van de Hulst
- Detected in 1951 by H. Ewen and E. Purcell at Harvard
  - Clouds near the galactic plane
- First maps of the galaxy were made in 1952
  - Revealed the spiral structure of the Milky Way

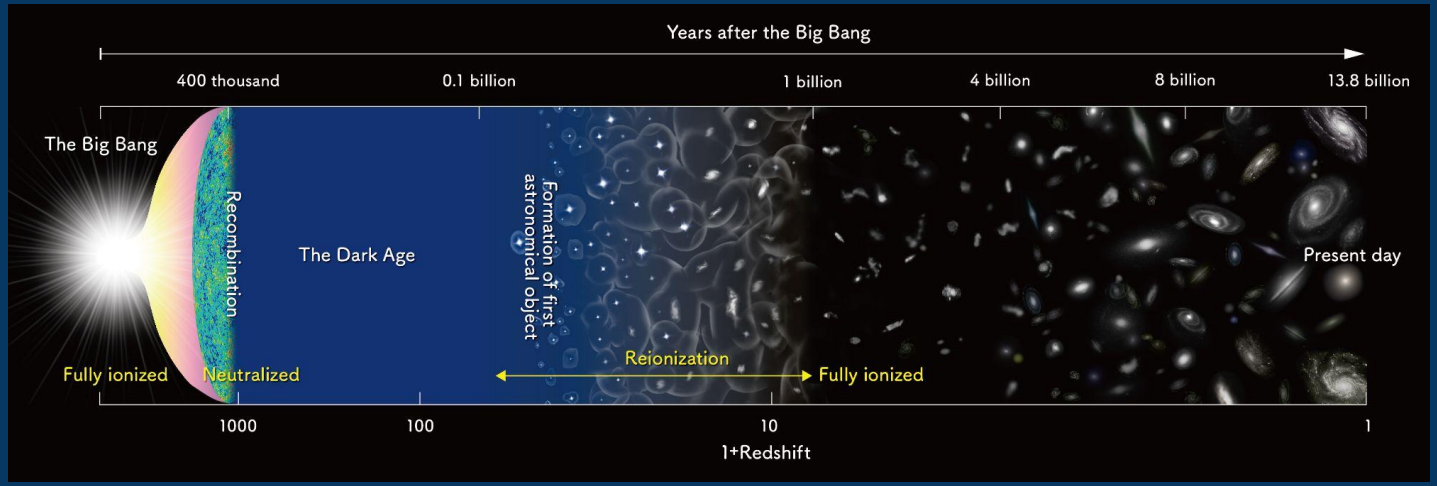
# Local Universe uses

- Calculate rotation curve of galaxies
  - This has provided evidence of dark matter
- Distance to pulsars in the galactic plane
- Mapping shape and structure of galaxies



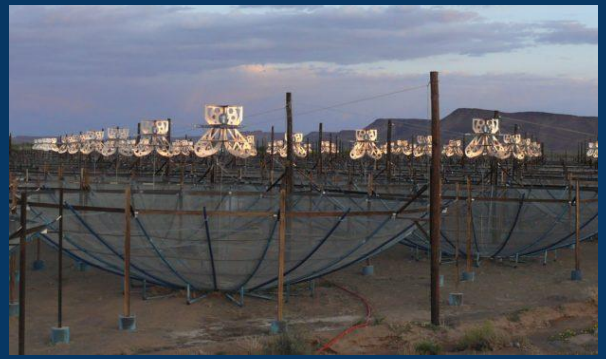
# Dark Ages, Cosmic Dawn, Reionization




- Mapping ionization bubbles
- Detecting neutral hydrogen in the Dark Ages
- Finding first stars and galaxies in the Cosmic Dawn

# Current 21-cm Experiments and Telescopes

- MWA
- LWA
- VLA
- HERA
- LOFAR



# Suggested Reading

Review article: 21 cm cosmology in the 21st century, Jonathan R Pritchard and Abraham Loeb, 2012

In-depth: Cosmology at Low Frequencies: The 21 cm Transition and the High-Redshift Universe, Steven R. Furlanetto, S. Peng Oh, and Frank H. Briggs, 2006

Data Analysis and instrumentation: Data Analysis for Precision 21 cm Cosmology, Adrian Liu and J. Richard Shaw, 2019