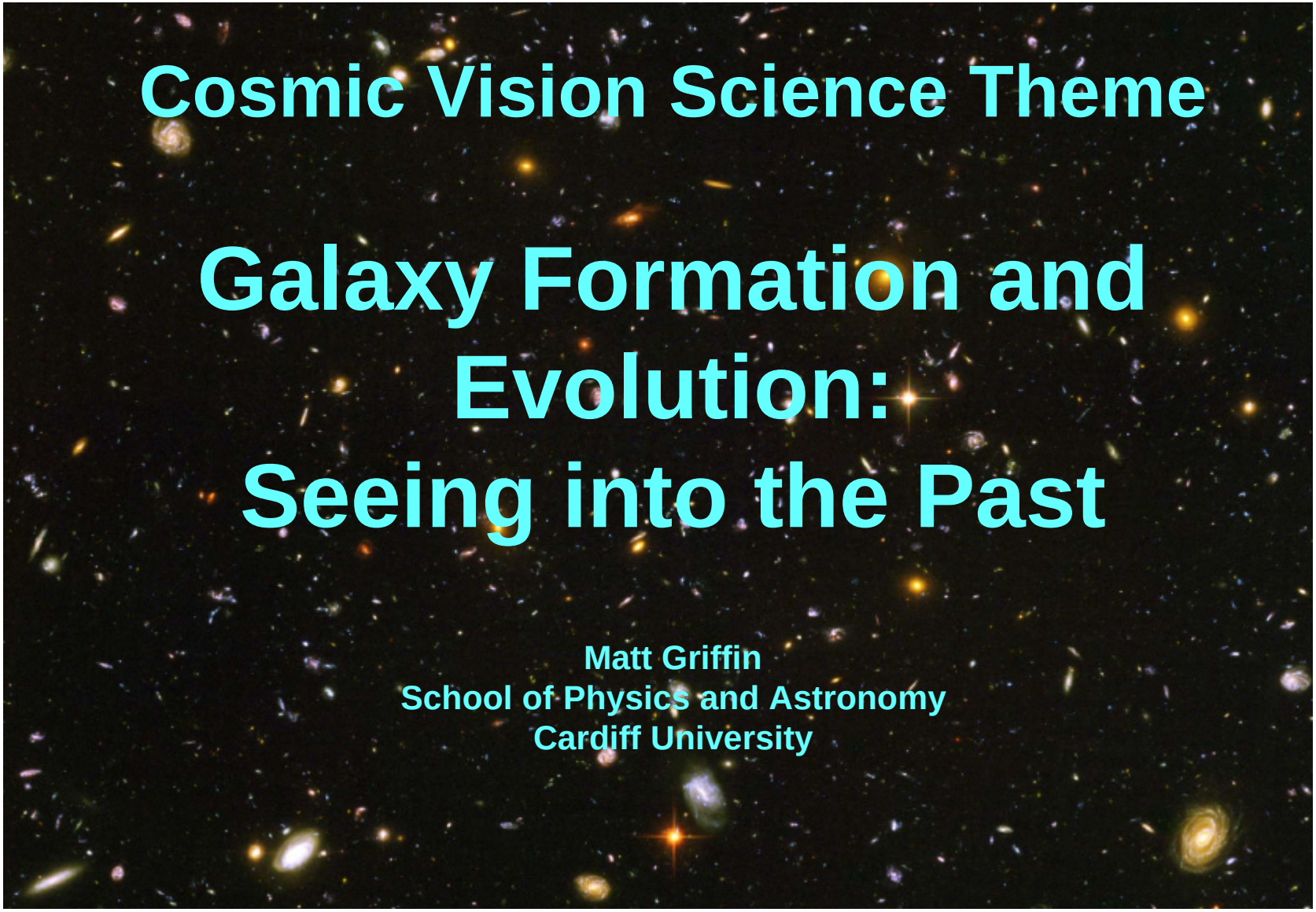
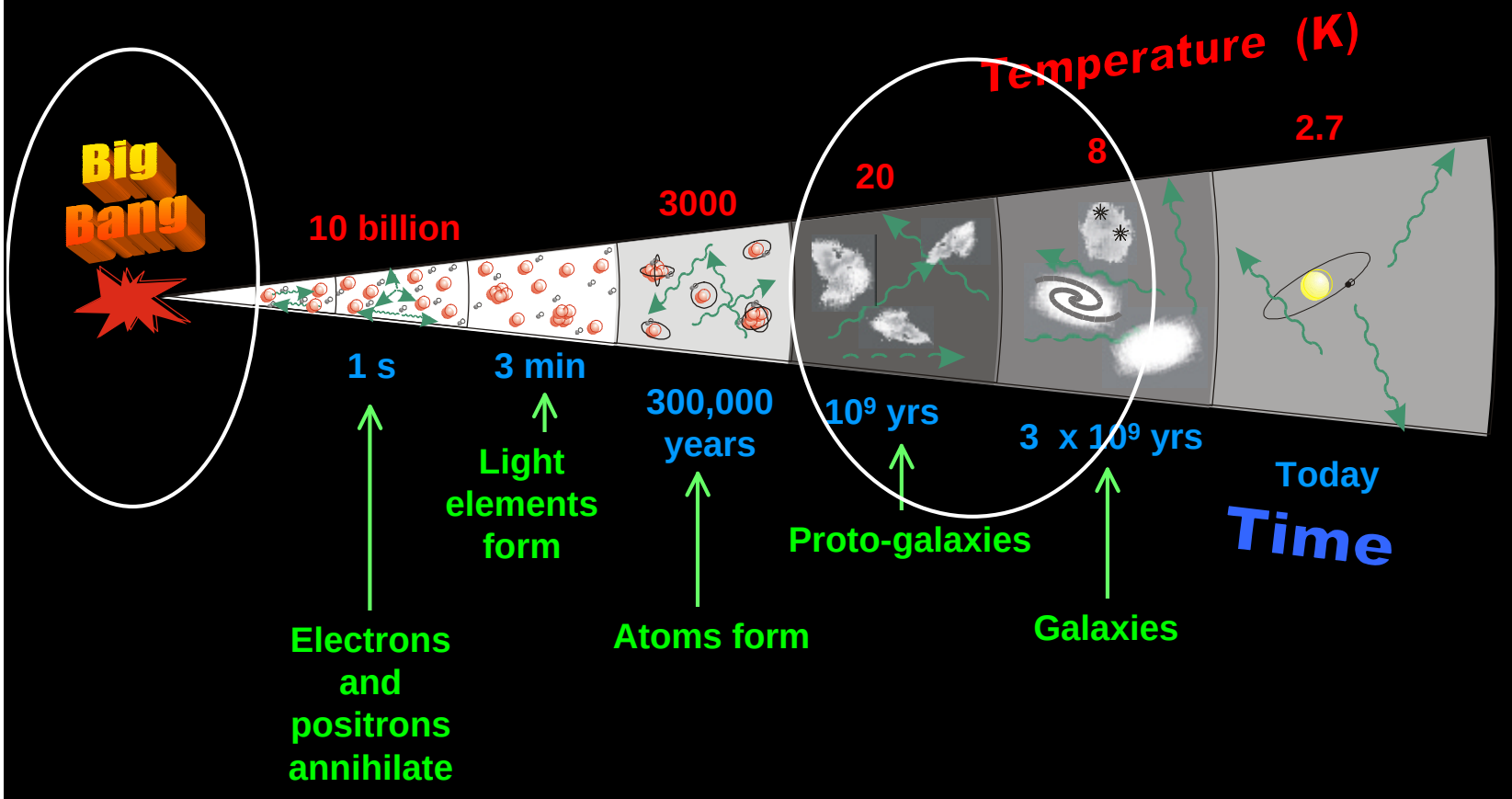
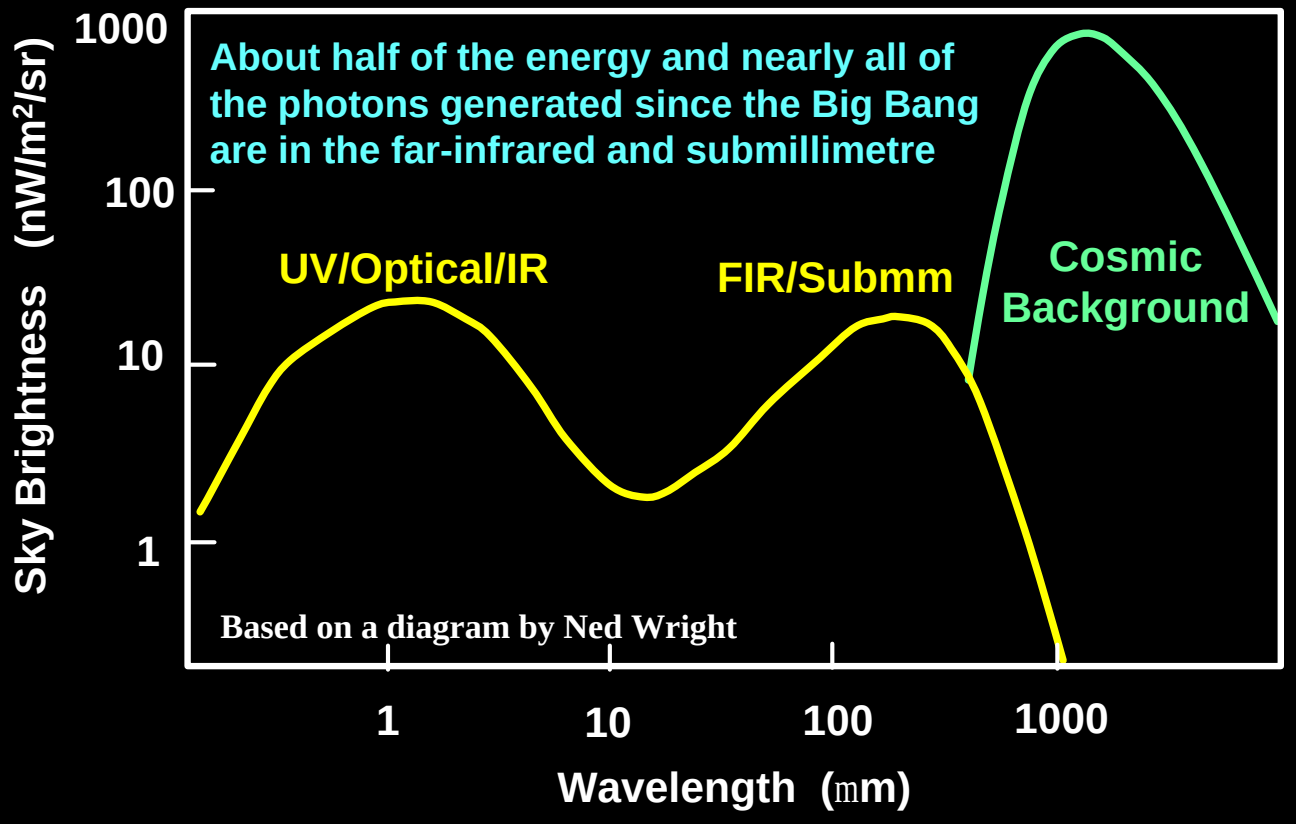

Cosmic Vision Science Theme
Galaxy Formation and Evolution:
Seeing into the Past
Matt Griffin
School of Physics and Astronomy
Cardiff University

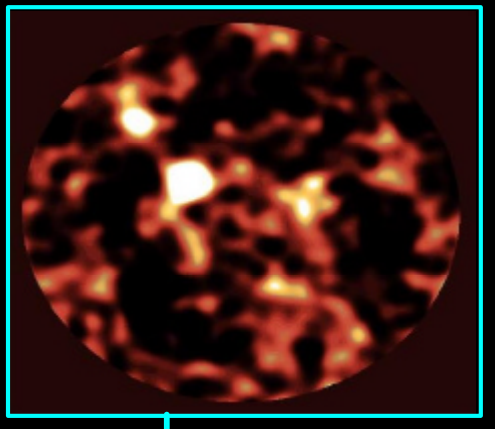
The History of the Universe

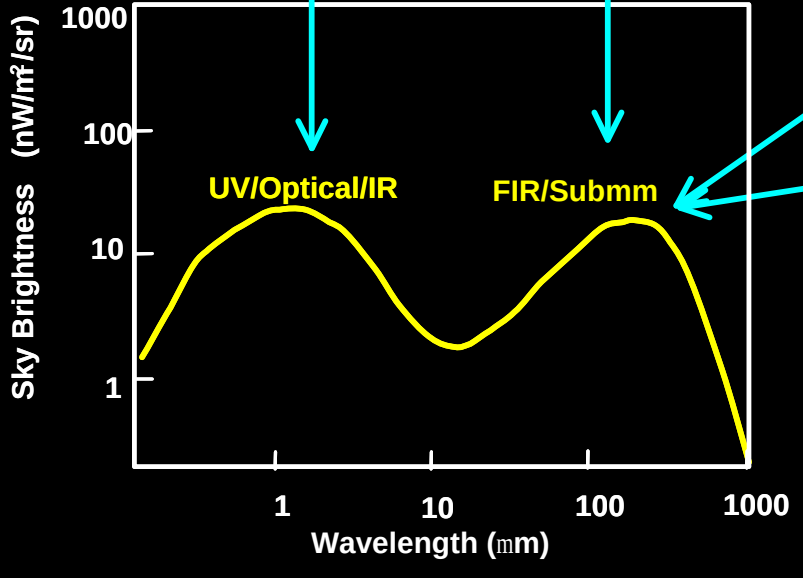


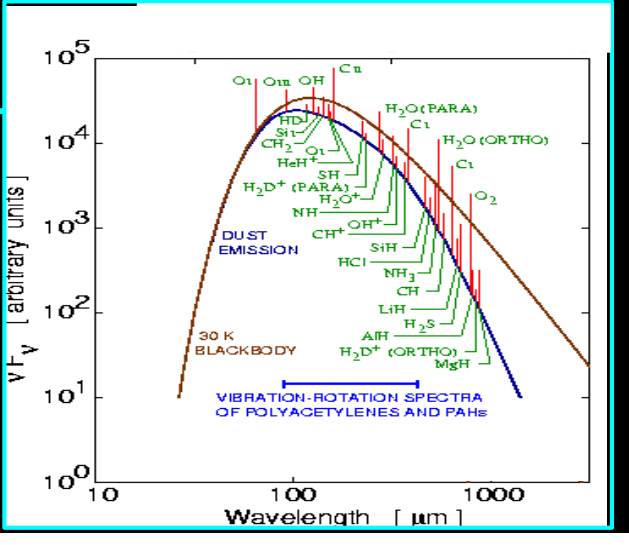
Spectral Energy Distribution of the Universe



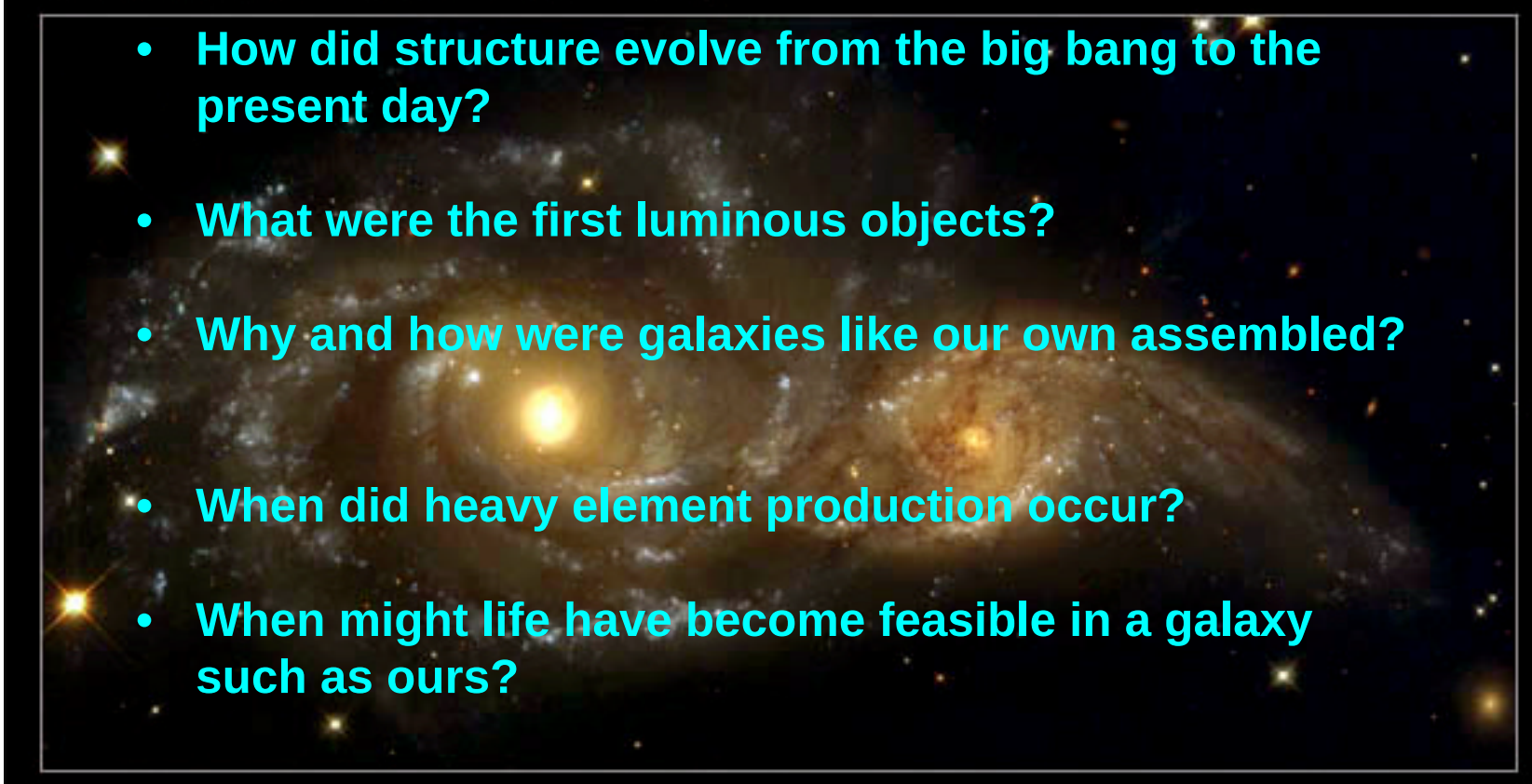
The Cosmic Infrared Background







Galaxy Formation: Key Scientific Questions

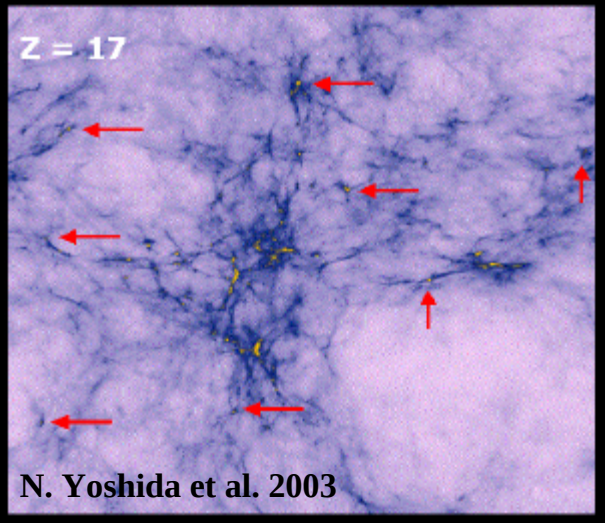


- How did structure evolve from the big bang to the present day?
- What were the first luminous objects?
- Why and how were galaxies like our own assembled?
- When did heavy element production occur?
- When might life have become feasible in a galaxy such as ours?

Galaxy Formation:

Key Observational Goals

First Light: Detect the Very First Stars as they Formed



- First objects formed from clouds of H and He
- Rotational H_2 lines (7 – 30 mm rest frame) cool the condensing gas
  - redshifted to FIR for *z* ~ 10 - 20
  - unique signature of the first collapsing objects
- Large amounts of H_2 gas reformed due to shocks from first supernovae
- Re-ionisation of the Universe at z ~ 20
- Production of first heavy elements which influence future star and galaxy formation

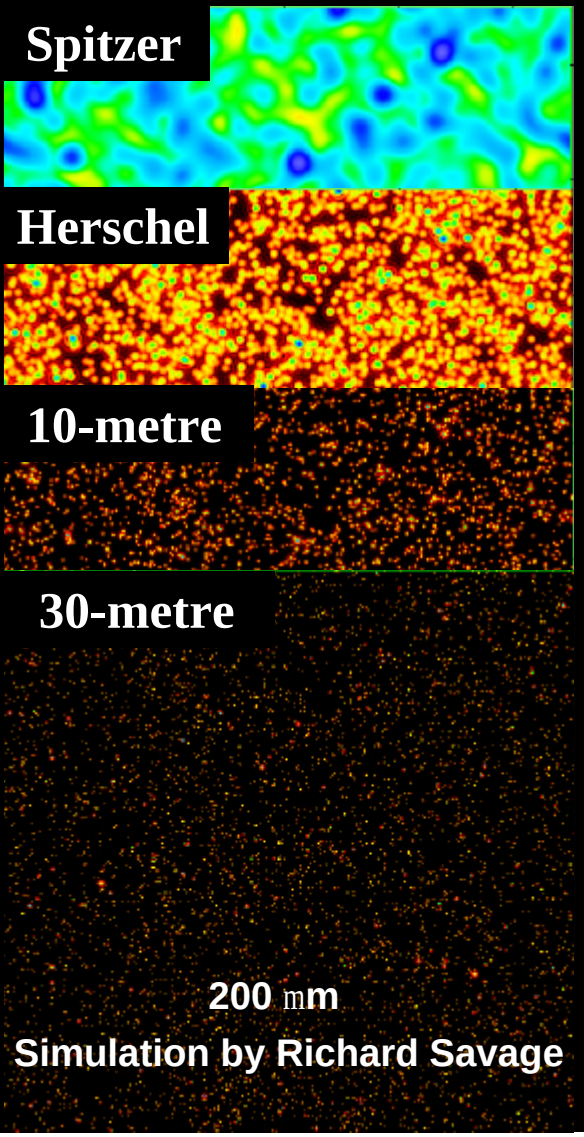
FIR background: Resolve the Galaxies and Study them Spectroscopically

- FIR and submillimetre surveys are resolving *some* of the background into discrete galaxies

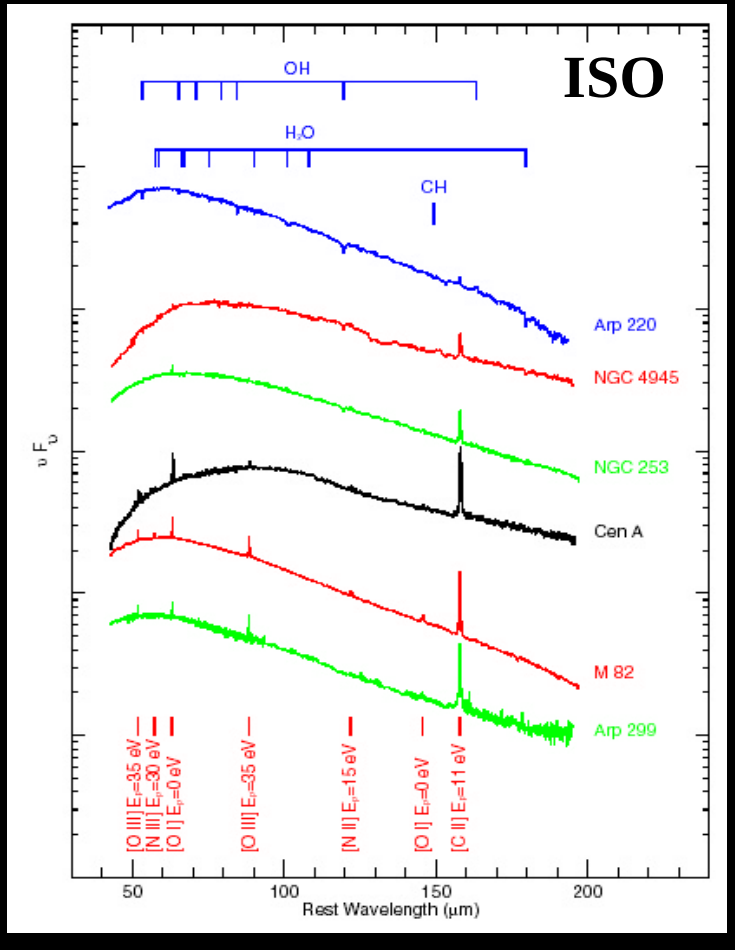
- But

- The contribution of the progenitors of normal galaxies is unknown

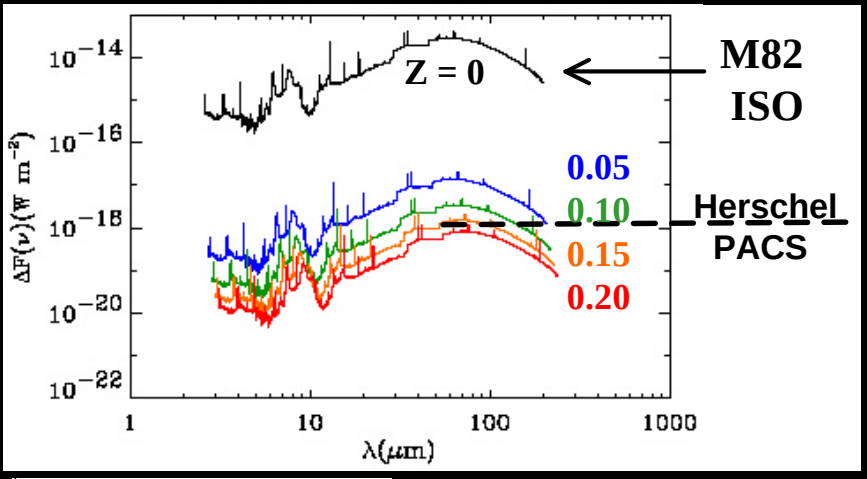
- Redshifts, luminosities, knowledge of physical and chemical nature, require <u>spectroscopy of individual galaxies</u>

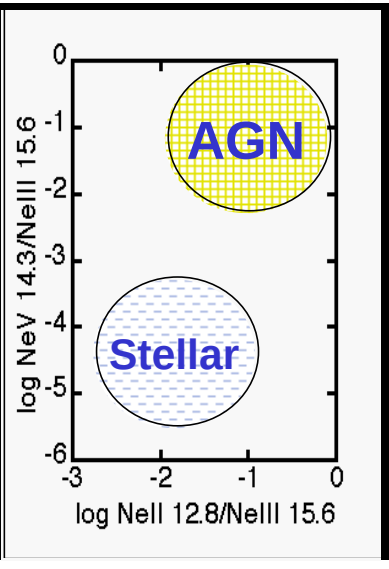


FIR Spectroscopy of Galaxies



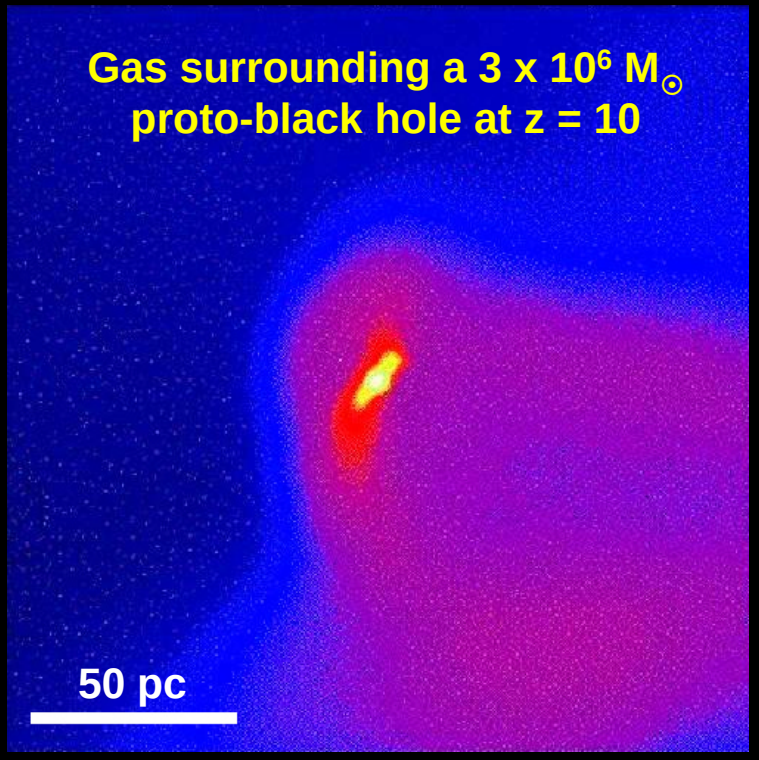
J. Fischer et al.





Fine-structure line ratios tell us whether star formation or accretion onto a black hole is the power source

Determine the Role of Black Holes in Galaxy Formation and Development

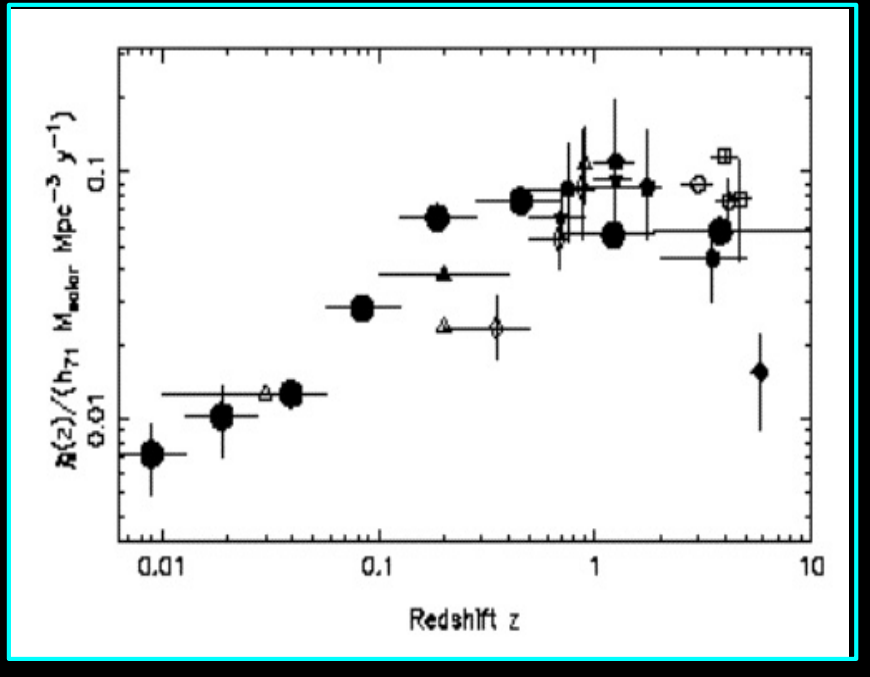


Simulation by Bromm and Loeb, 2003

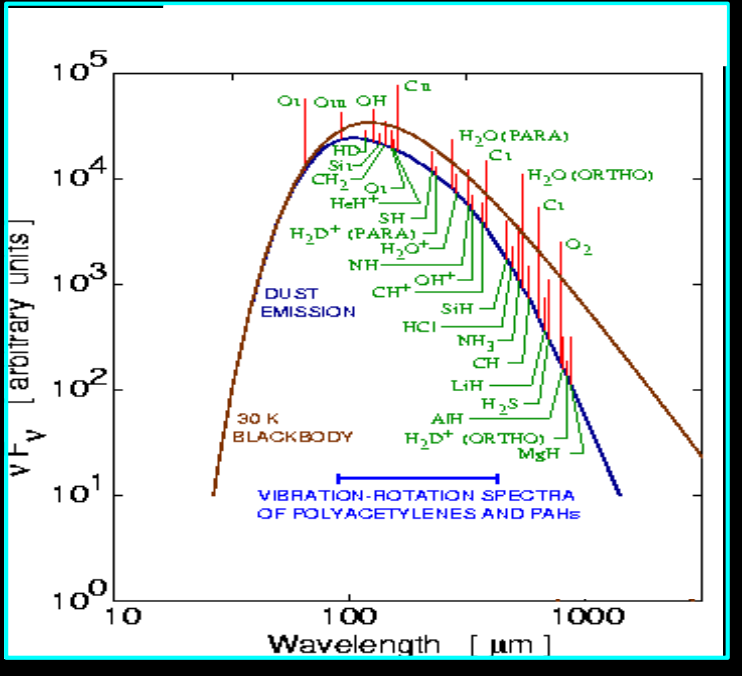
- Seed black holes formation before reionization?
- Black hole collapse
  - From dense star cluster or single supermassive star?
  - Direct collapse from a dense gas cloud?
- Earliest quasars found so far are already heavily metal-enriched
- Obscuration
  - Initial accretion embedded in Compton-thick gas
  - Black hole hidden by metals and dust from its conception as surrounding gas forms stars
  - Only detectable in the FIR

Energy Production and Build-up of Heavy Elements: Measure the Star Formation and Chemical History of Galaxies to z > 5 in a Completely Unbiased Way

Star Formation History

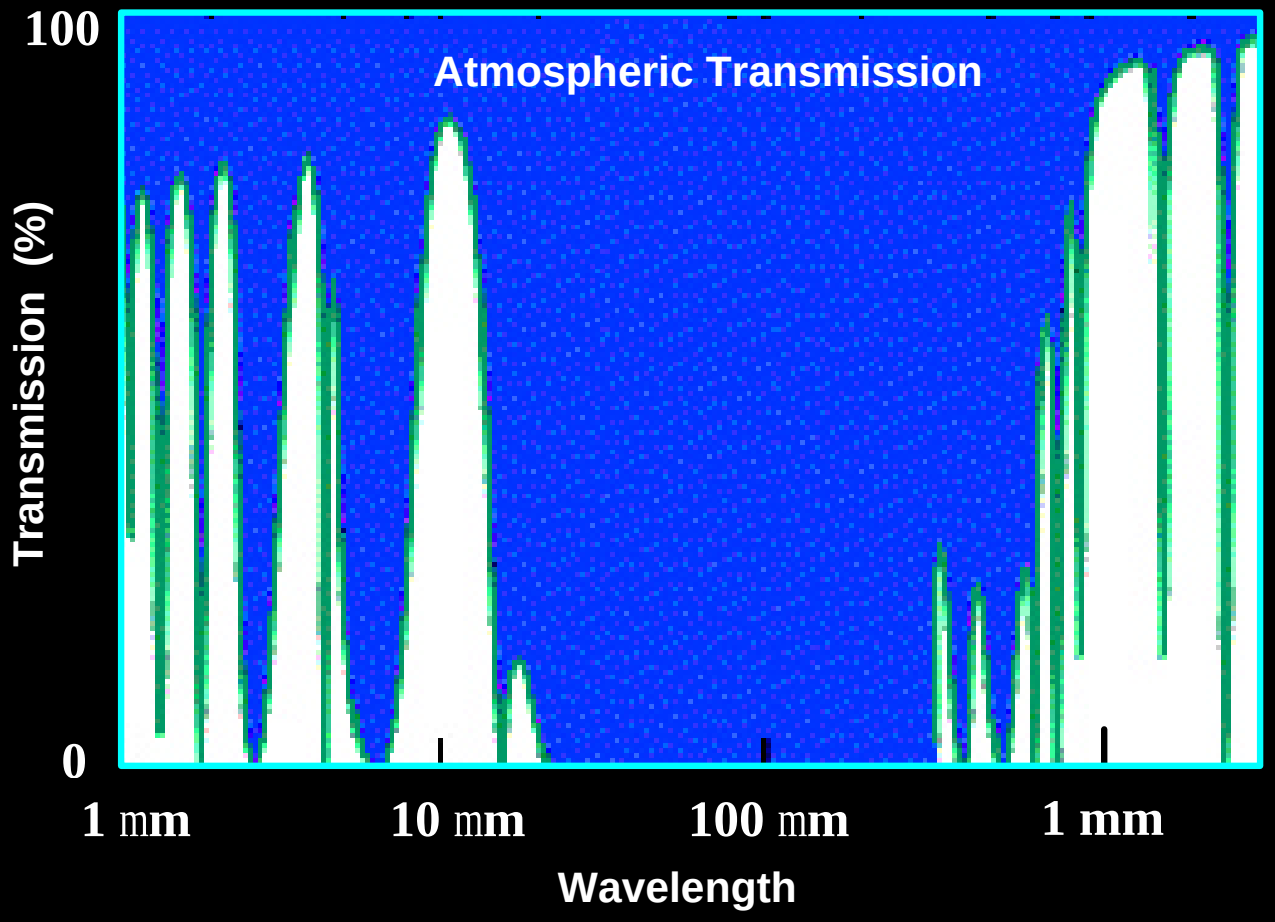


Chemistry

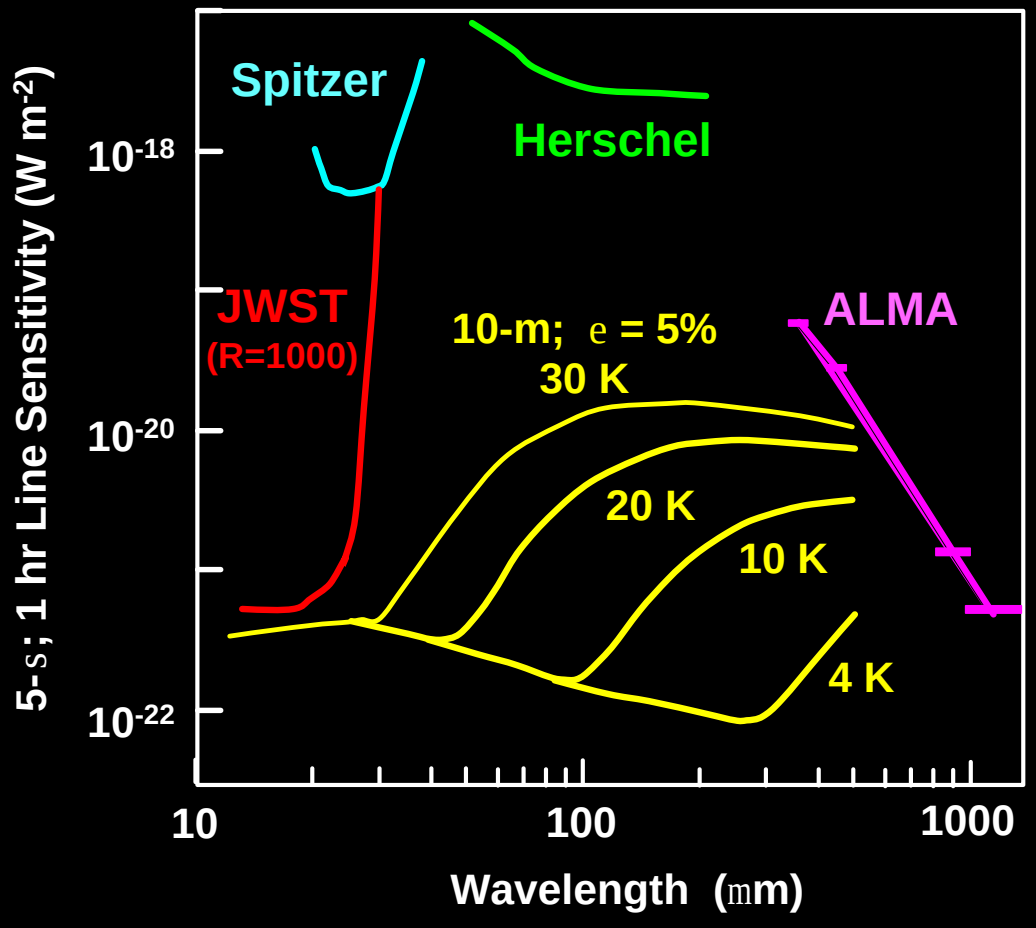


How Can We Do This?

Need for Space



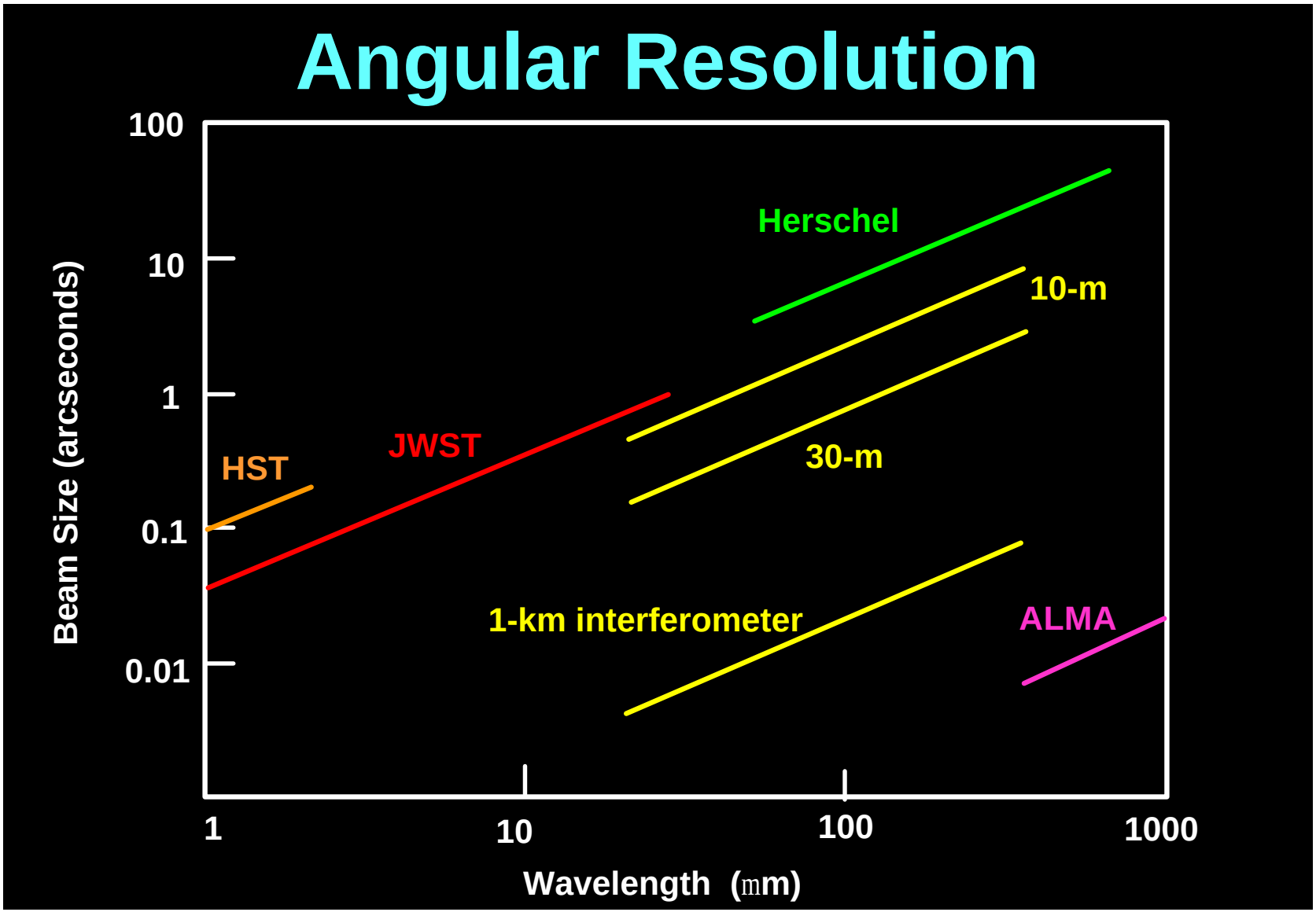
Sensitivity



A 4-K telescope is background-limited:

- **Zodiacal light below 200 μm**
- **CMB above 200 μm**

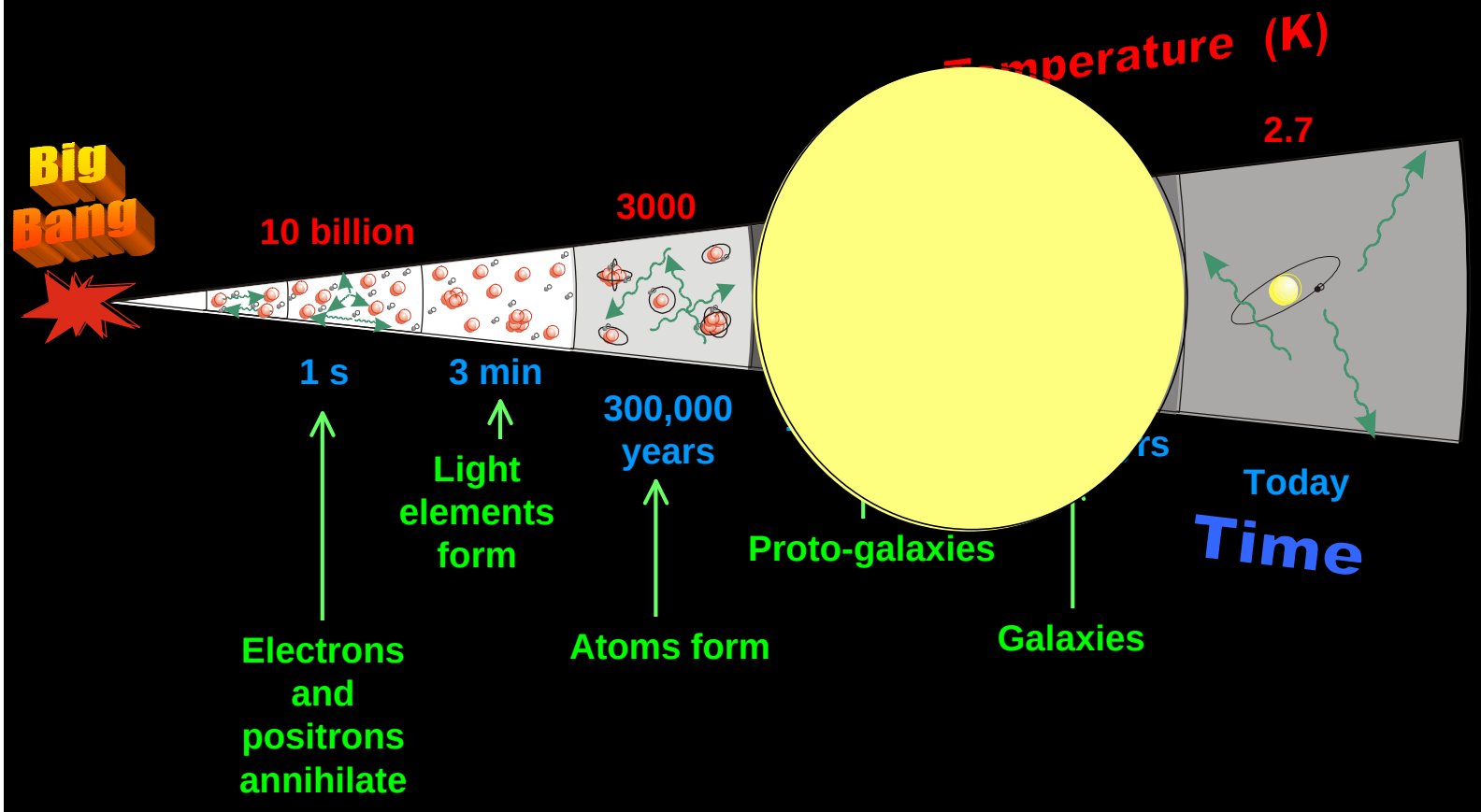
Angular Resolution



Technical Needs

- **Actively cooled telescopes:**
  - Limited by natural astrophysical backgrounds
- **A new generation of cryogenic detectors and instruments:**
  - Large-format arrays with sensitivity 10 - 100 times better than the current generation of detectors
  - Ultra-low background instrument design
- **Large aperture or interferometer for angular resolution:**
  - 10-m single dish
    - Observing speed for deep imaging
    - Sensitive spectroscopy
  - > 30-m: Resolve all of the FIR background
  - ~ 1 km: HST resolution in the FIR
- **The core technological capabilities for all of these exist in Europe**

The History of the Universe



The History of the Universe