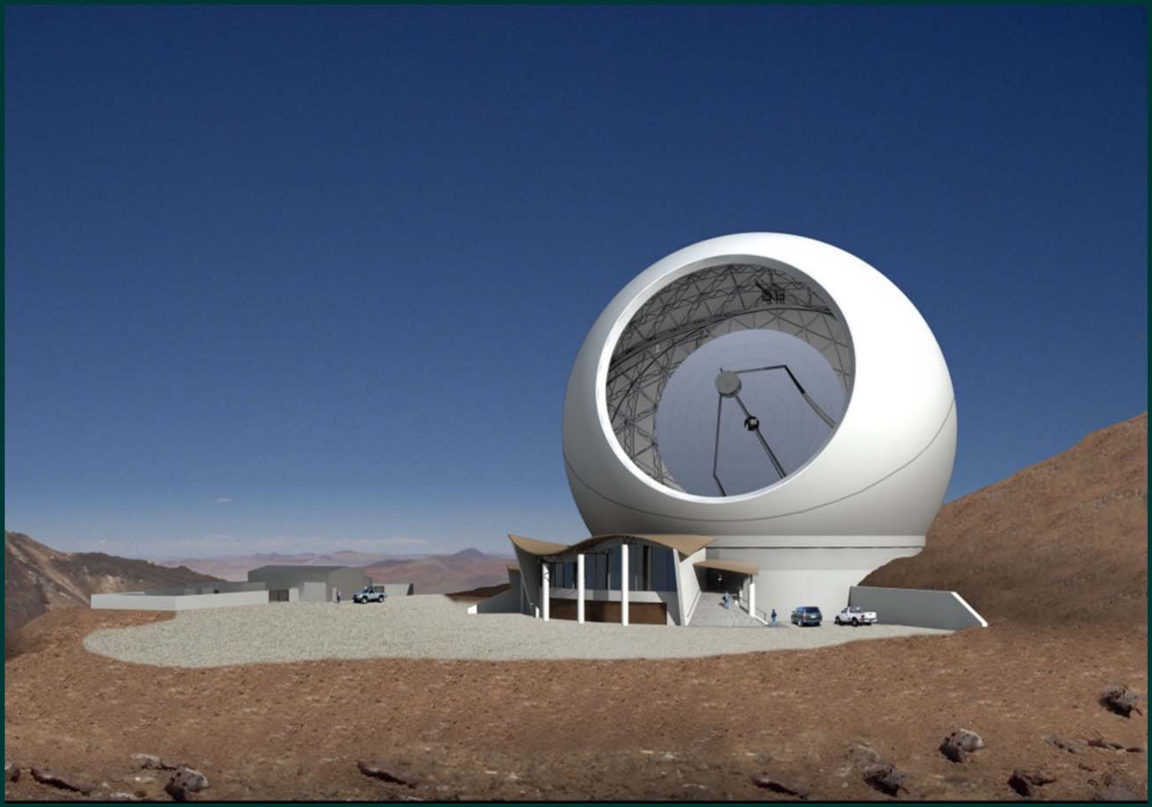
Astrophysics with CCAT

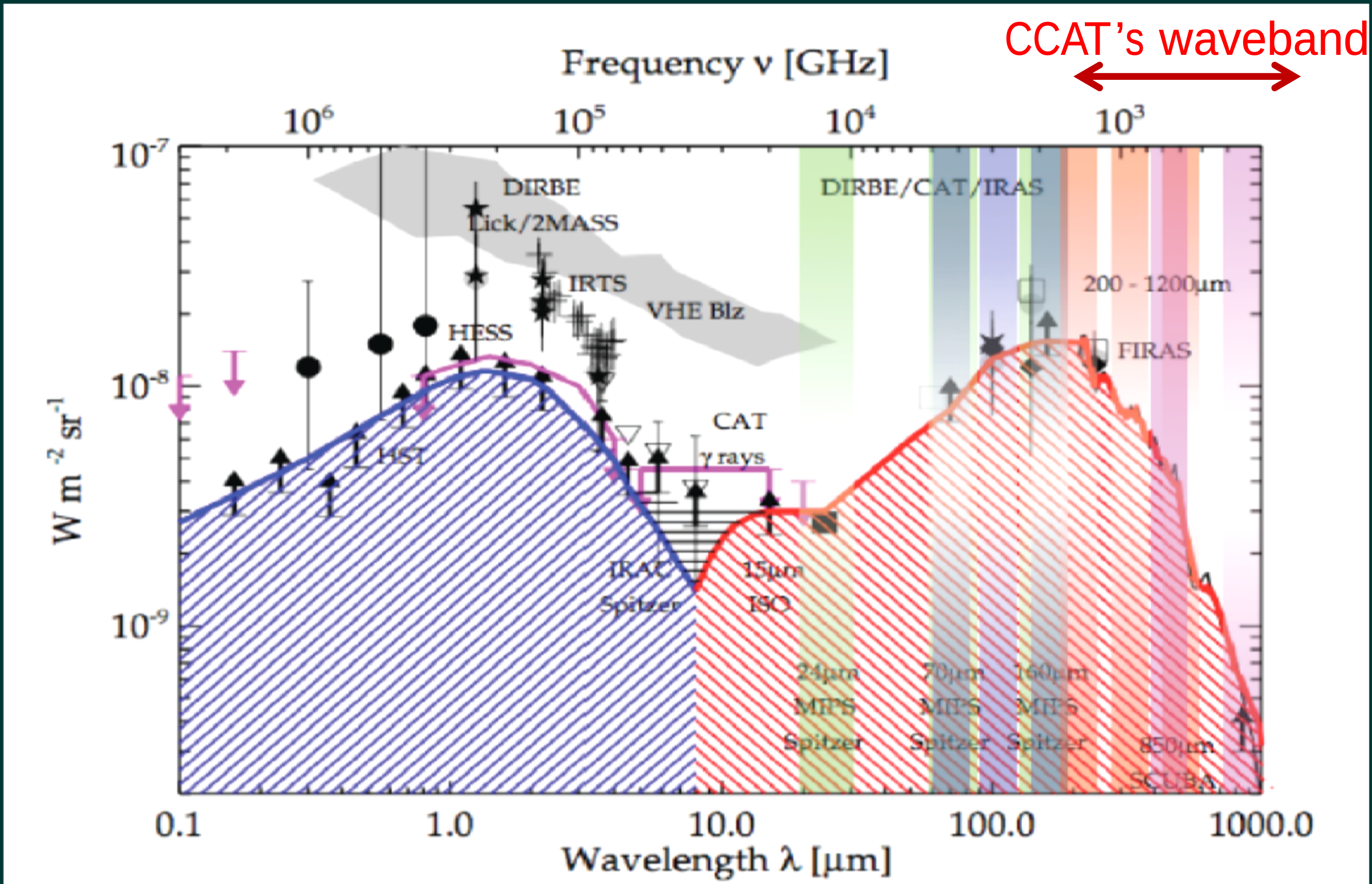


http://www.submm.org

- Site: Cerro Chajnantor, Chile (5,600m)
- Partners: Cornell, Caltech, Germany (Univ. of Cologne), CU, Canadian consortium, AUI
- Aperture: 25-m
- Angular Resolution: 3.5" beams @ 350 μm
- Wavelengths: 200 μm – 2.2 mm
- FOV: >20' (1°)
- Cost: ~$110M
- Schedule: *Target* completion 2017

Likely first-light instrumentation: 6.5' short-wave camera, 18' long-wave camera, spectrometer (MOS?)

Resolving the Cosmic FIR Background Radiation into Galaxies to Measure the Cosmic Star Formation History

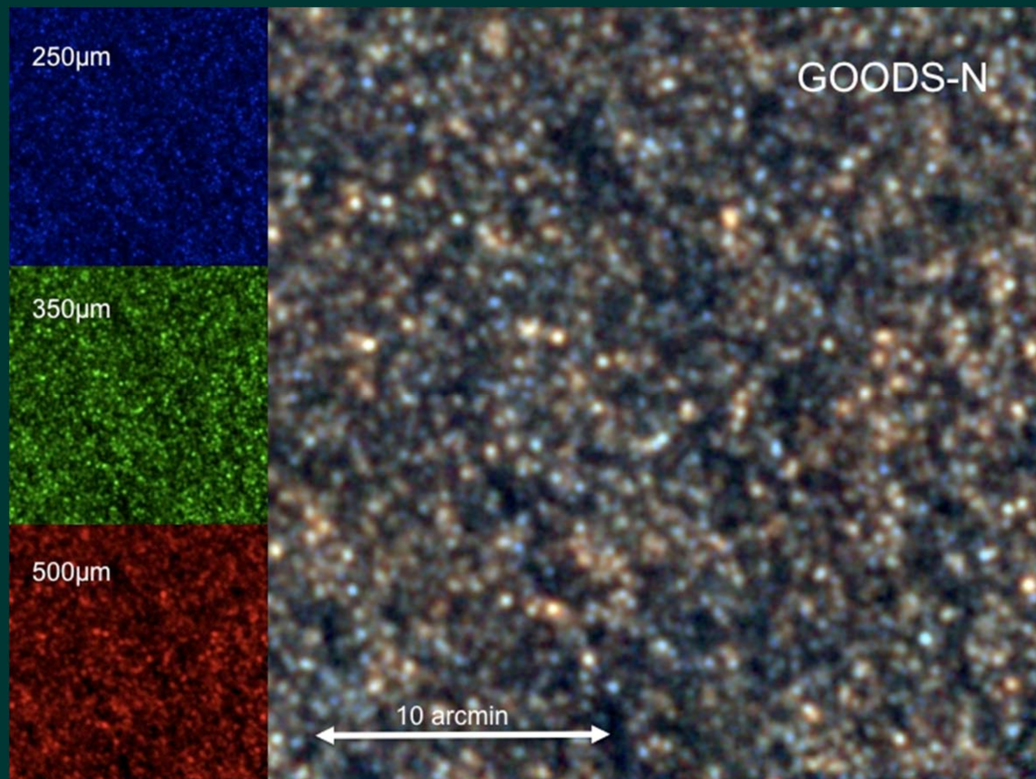


Dole et al. (2006) and S. Oliver

- 50% of the extragalactic background radiation is in the FIR/submm
- 10% of the FIR background has been resolved by number, 50% statistically
- The FIR/submm luminosity function evolves strongly for z > 0

Dusty, High-z Galaxies: the State of the Field

Herschel is enabling us to characterize the *bright end* of the submm galaxy population.

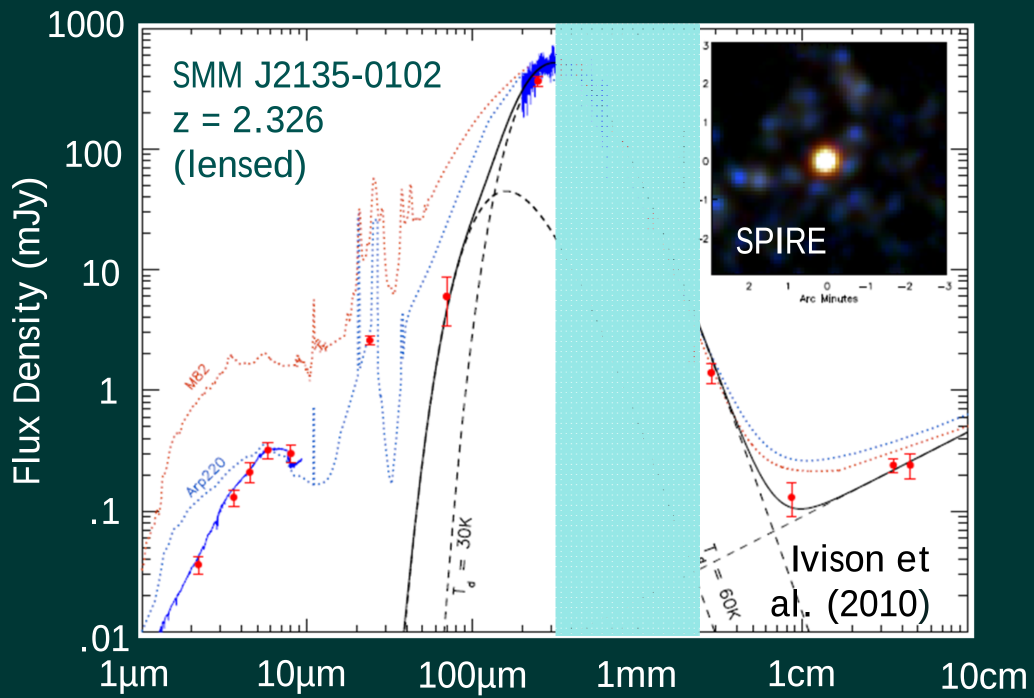


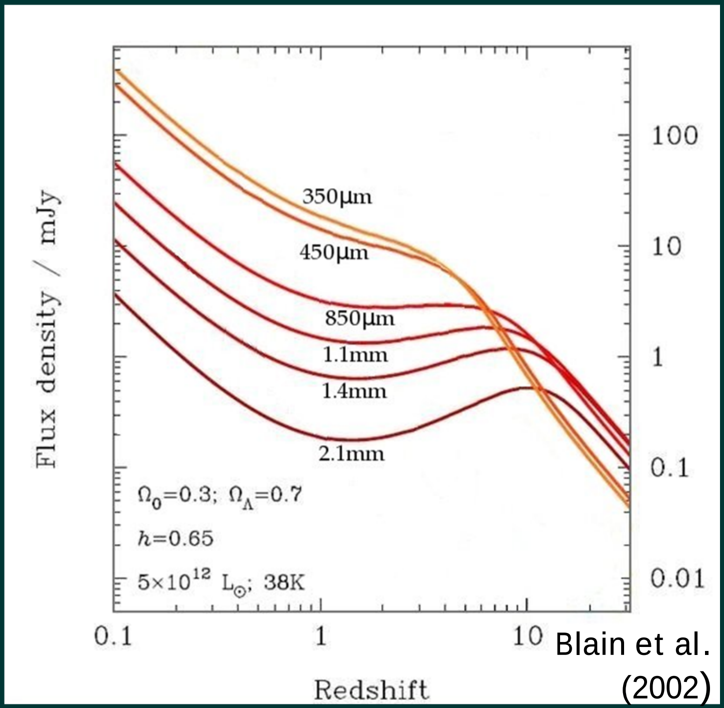
Courtesy HerMES and ESA

- Luminosities, FIR SEDs, and SFRs: large T_{dust} range observed (10–90 K)
- Number counts: Don't match pre-Herschel predictions well
- Halo masses: Brightest (> 30 mJy @ 250 μm in 19 sq. deg.) SMGs occupy $(5\pm4)\times10^{12}$ M_{sun} halos; 15% occupy more massive halos
- Source confusion is a fundamental limiter

Submillimeter Observations of Dusty High-z Galaxies

Submillimeter continuum: bolometric luminosities, star formation rates, dust temperatures and gas masses, sensitivity to high redshifts

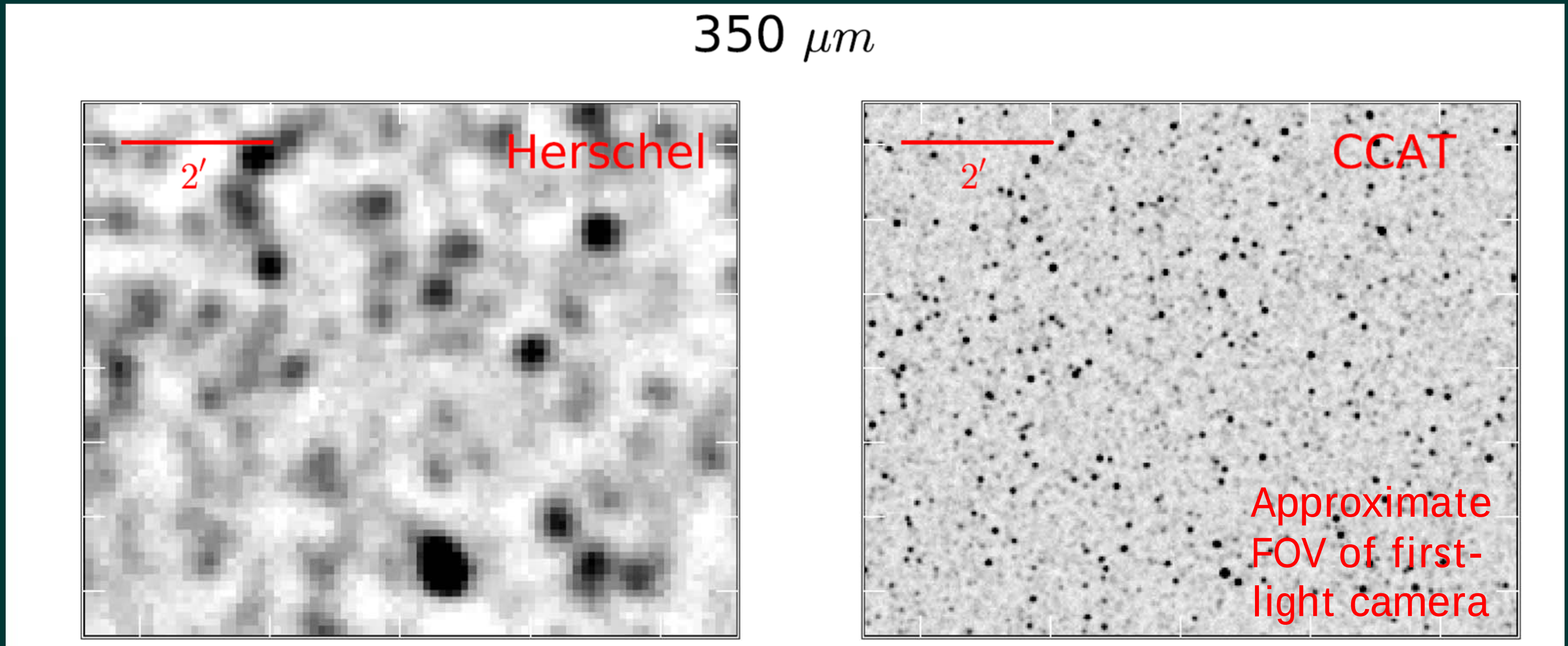




GCT: How do baryons cycle in and out of galaxies, and what do they do while they are there? A complete inventory of cold gas in and around galaxies is crucial for understanding baryon cycling.

→CCAT will assess the dust and cool gas content of galaxies from the nearby universe to high z

Solving the Confusion Issue

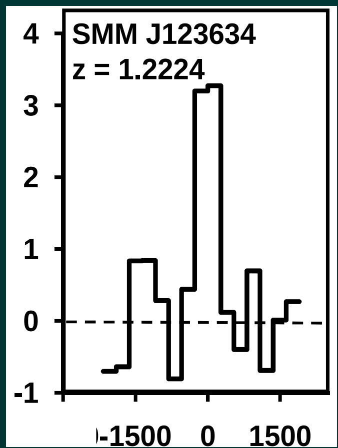


Simulated maps of the same patch of sky based on *Herschel* number counts

- Essentially 100% of the background can be resolved with a 4" beam
- Luminosity function measurement: ~10,000 galaxies will be detectable per square degree per ~2.5 weeks in continuum
- At 350 μm, at the 5σ confusion level, depths of
  - 2×10^{10} L_{sun} at z = 1
  - 10^{11} L_{sun} at z ~ 2.5
  - 10^{12} L_{sun} at z ~ 6
- CCAT will measure halo masses via clustering of galaxies almost two orders of magnitude fainter than *Herschel*, as a function of luminosity

Measuring Redshifts & Characterizing Interstellar Media

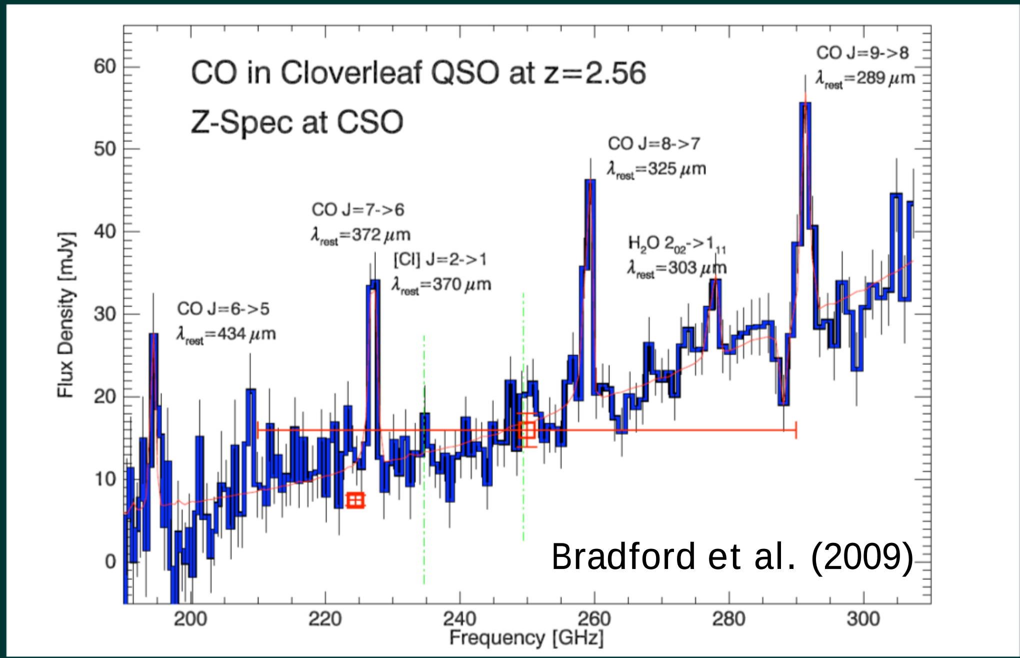
Atomic fine structure & molecular lines enable z's to be measured & T's, n's, M_{gas}'s, & G's to be measured and sources of excitation to be identified



Stacey & Hailey-Dunsheath et al.

ZEUS CSO

- G: 400 – 5000
- n: 10^3 – 10^4 cm^{-3}
- Starburst-dominated to AGN-dominated $L_{[CII]}$ / LFIR differs by ~8x



- T ~ 60 K, n ~ 10^3 cm^{-3}, P ~ $10^{5.5}$ K cm^{-3}
- $M(H_2)$ ~ $1x10^{10}$ M_{sun}
- CO excited by XDR; L_{FIR} likely derived from XDR and star formation

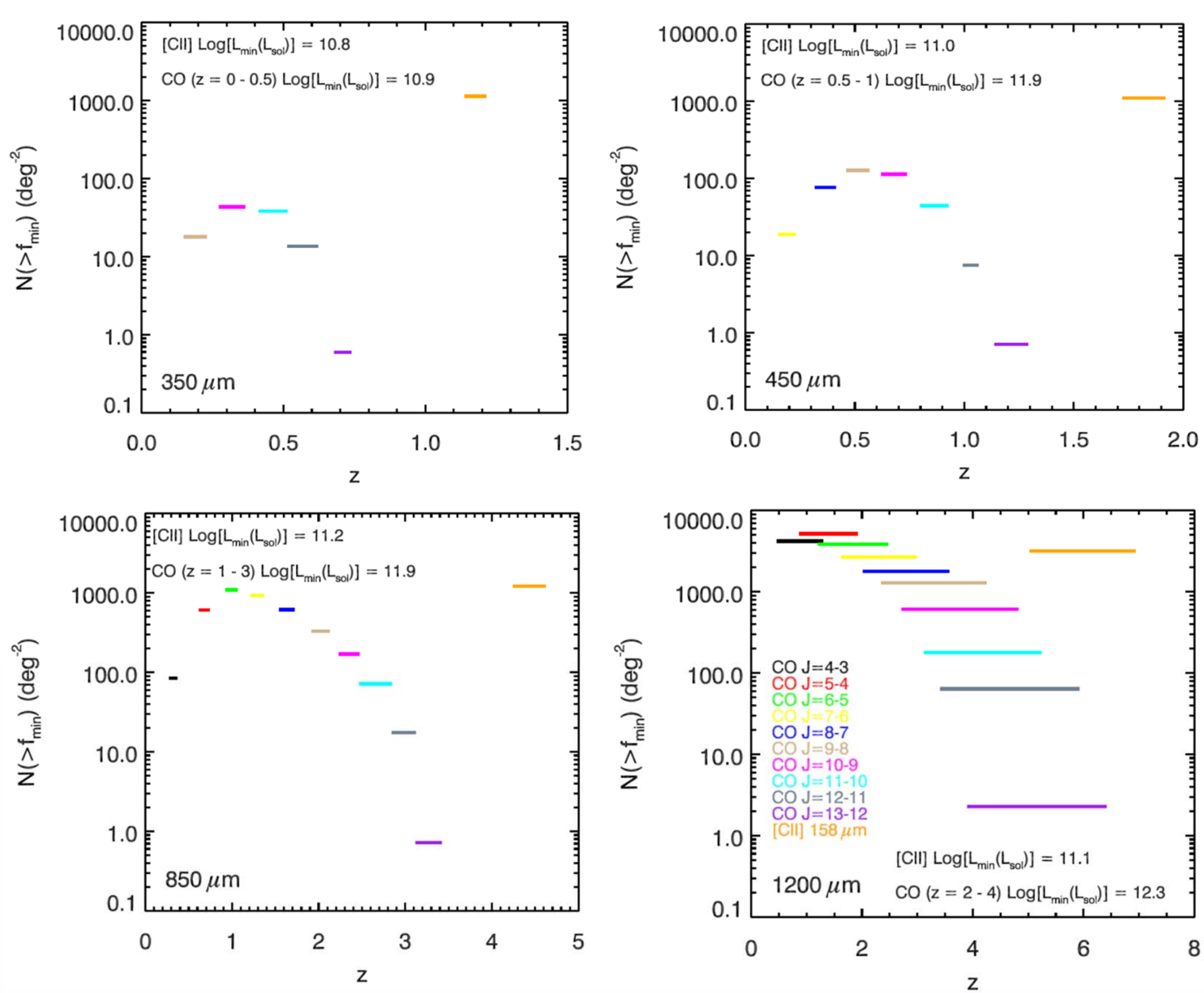
GCT: How do black holes work and influence their surroundings? How does black hole feedback shape the evolution of cosmic structures?

→CCAT will assess the AGN influence on star-forming gas in galaxies from molecular atomic gas spectral energy distributions

How Many High-z Galaxies Can CCAT Detect Spectroscopically?

And, what kind of spectrometer does CCAT need?

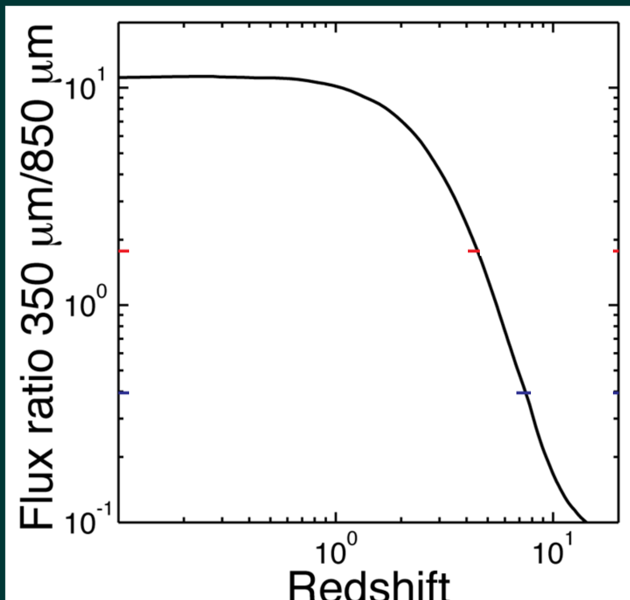
Other fine-structure lines will be detectable at high z: [OI] 63 & 146 µm, [NII] 122 & 205 µm



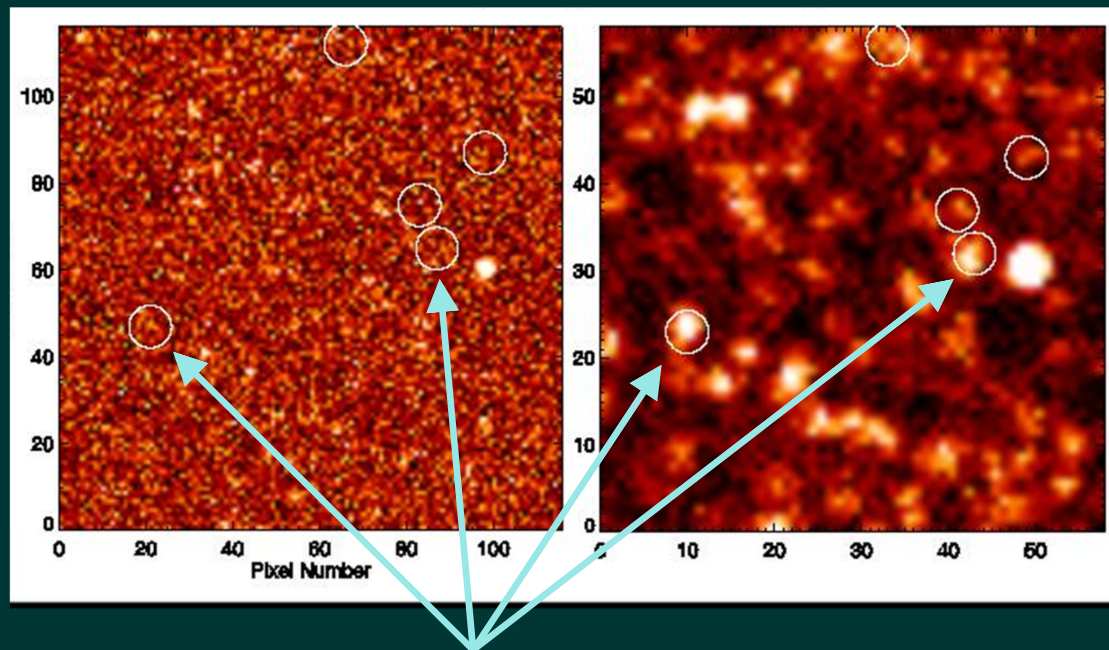
Identifying Very High-z Galaxy Candidates

High-z galaxies will have low 350 μm to 850 μm flux density ratios ("350 μm dropouts") and may enable us to probe the epoch of reionization

Observed flux density ratio



Simulated 350 μm and 850 μm maps



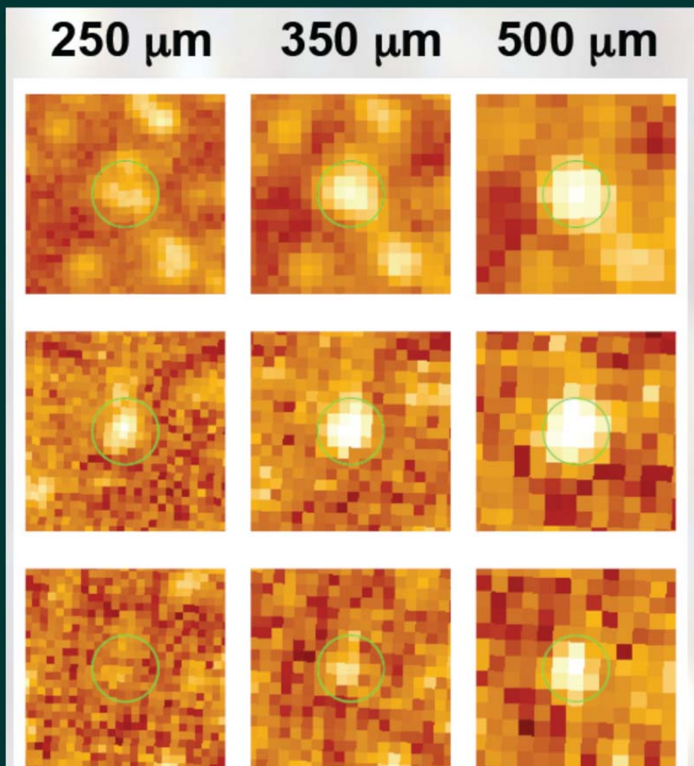
350 μm dropouts

GCT: What were the first objects to light up the Universe and when did they do it?
→Submm/mm colors and spectroscopy provide powerful methods for selecting high-z galaxies, those forming during the epoch of reionization.

Very High Redshift Galaxy Candidates

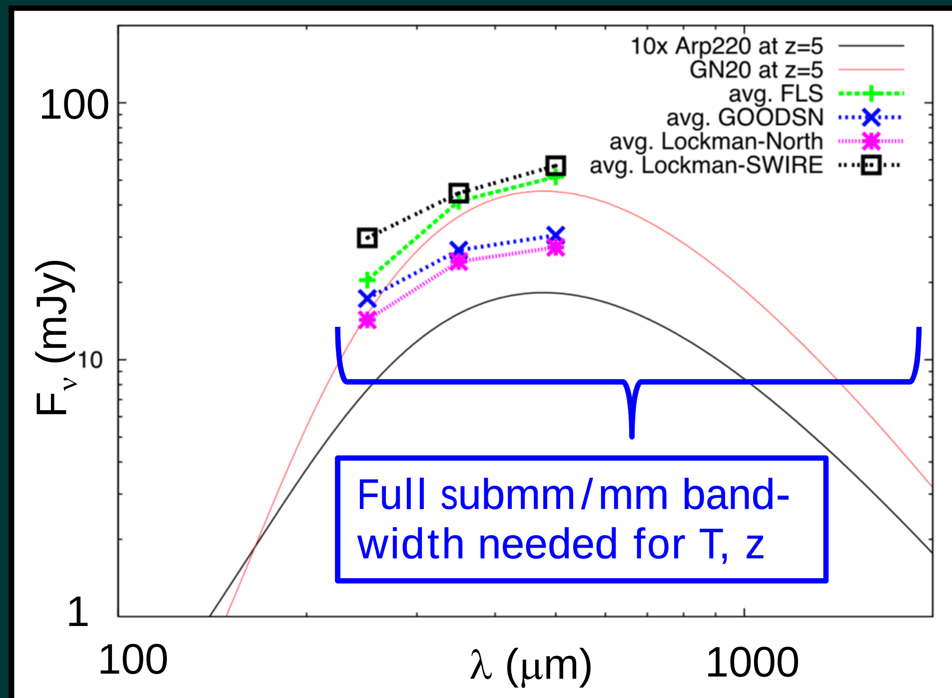
Herschel rising-spectrum sources

Three examples:



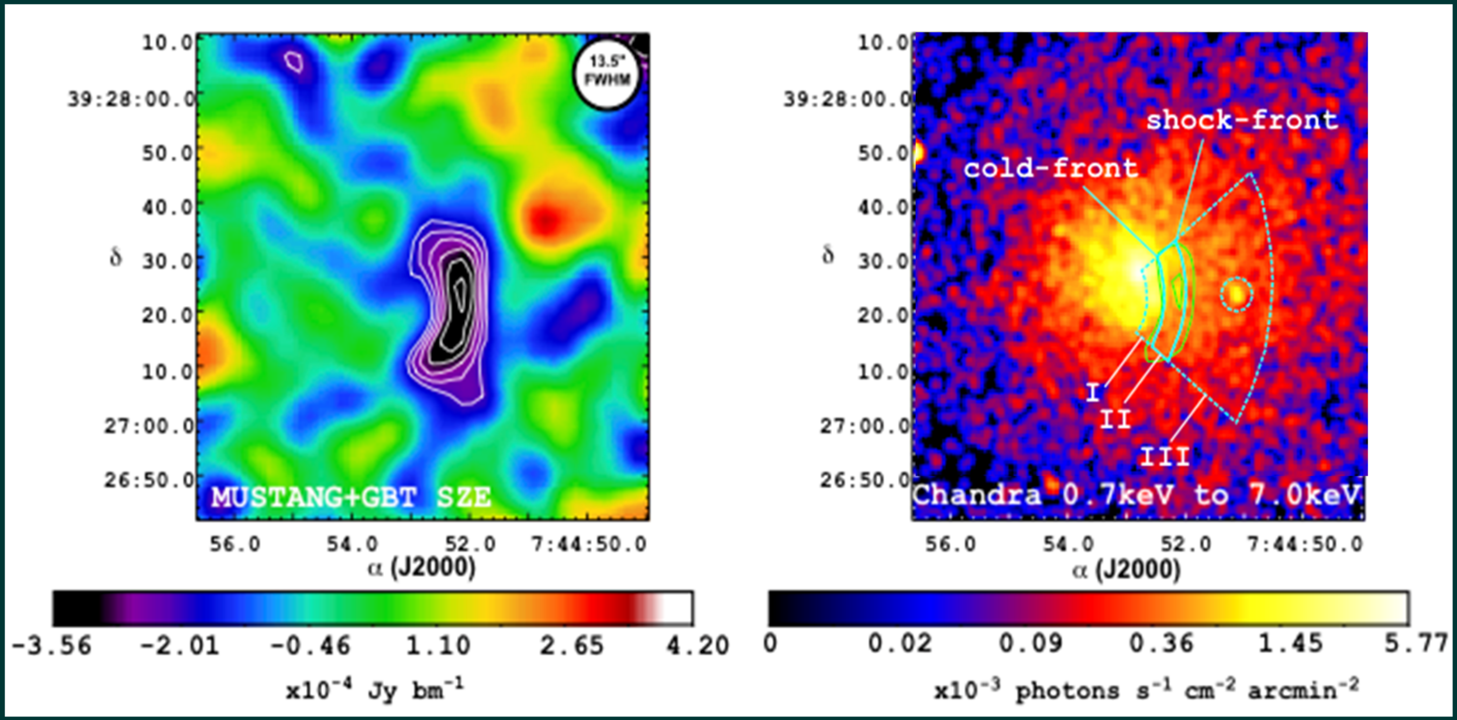
Dowell et al. (2011)

Average spectra of sources detected in 4 HerMES fields compared to templates:



Galaxy Cluster Astrophysics with CCAT

MACS J0744+3927 (z = 0.69), Korngut, et al., 2011

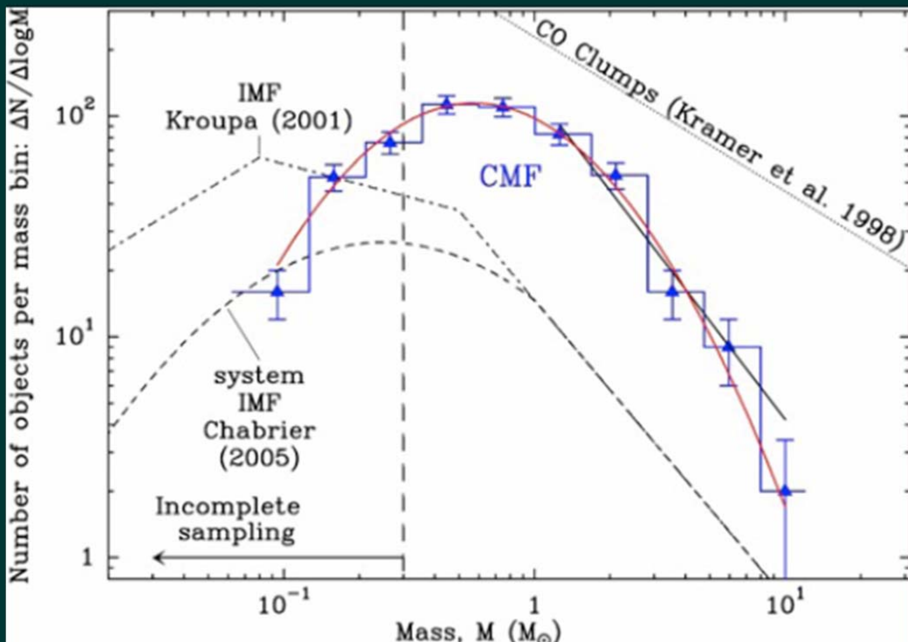


- >20‘ FoV: high-fidelity measurements to virial radii for total baryonic masses
- Sufficient angular resolution to measure ICM structure to see infall
- Submm + mm λs will enable dusty galaxies to be removed securely

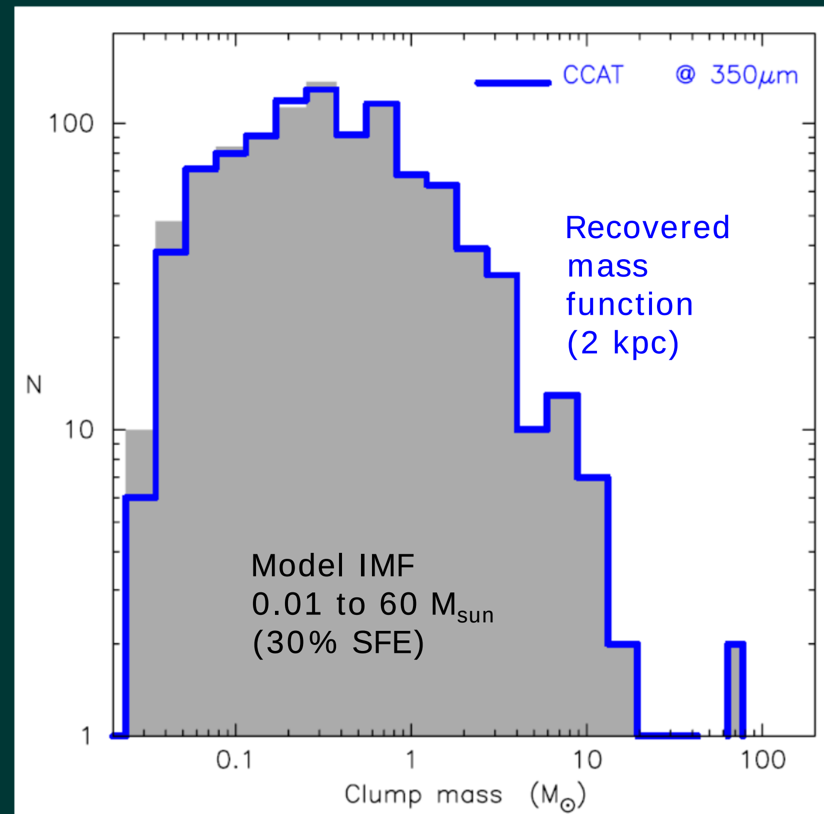
GCT: How do cosmic structures form and evolve?

→CCAT will measure the baryonic content and thermodynamic state of intracluster gas out to virial radii over a broad range of redshifts.

Measuring the Mass Function of Cloud Cores



Figures courtesy
John Carpenter



- The clump mass function is similar to the stellar IMF (*to completeness*)
- Submillimeter photometry is required to measure temperatures, bolometric luminosities, and precise masses

PSF: What is the origin of the stellar mass function?

→CCAT will measure the clump mass function to the substellar regime and determine if it follows the stellar IMF.

Conclusions: Some Astrophysics Goals for CCAT

1. Measure the star formation activity and gas reservoirs in galaxies over a broad range in luminosities through the peak epoch of star formation to high redshifts

2. Characterize the intracluster medium in clusters with high fidelity

3. Measure the molecular cloud clump mass function

Enabled by: spectral coverage, sensitivity, FoV, angular resolution, new detector array technology