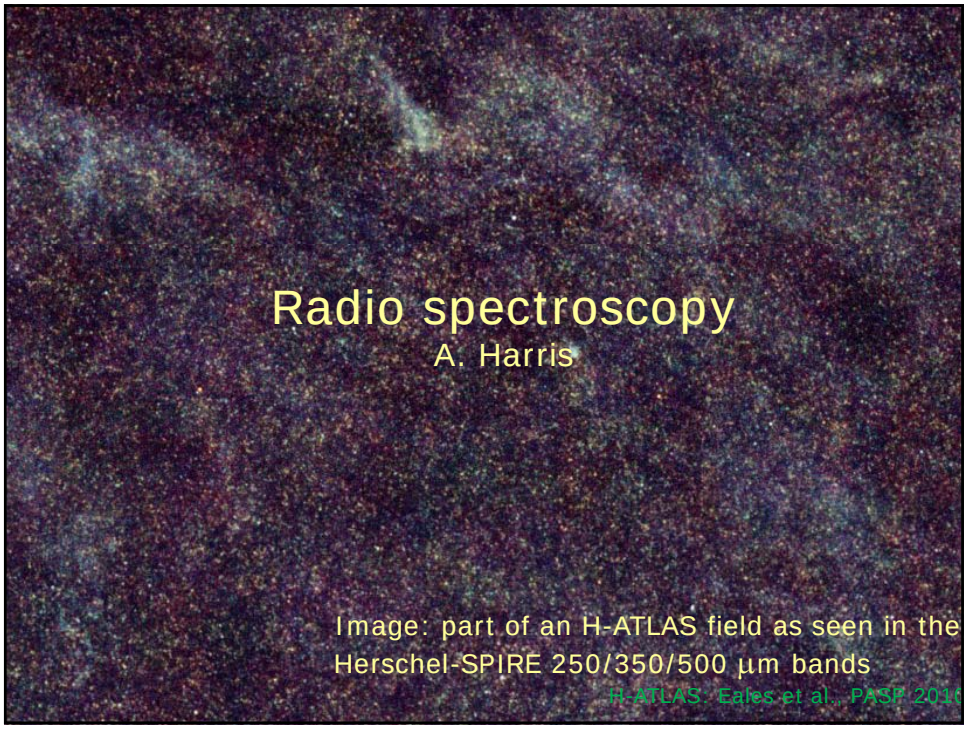


Annoying question at a NSF Science and Technology Center Review

"Are the graduate students being properly prepared to enter the 21st century job market?"

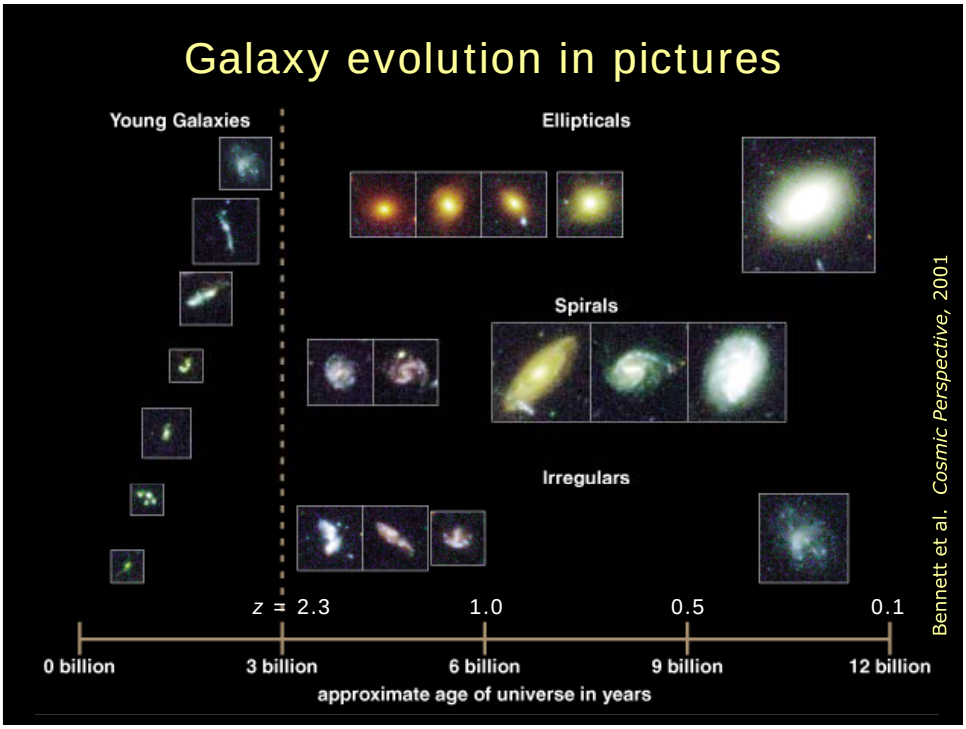
General, strong background:
- Physics
- Applied math
- Computer science

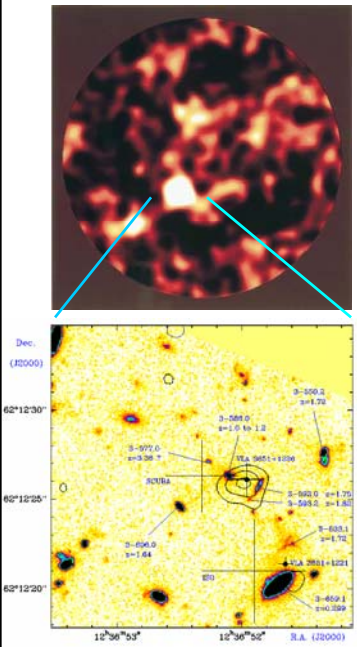
Diverse and useful skills:
- Computing (programming, modeling)
- Instrumentation

Key questions in radio astronomy

- Among the most important topics in radio astronomy are:
  - Structure in the Cosmic Microwave Background (power spectrum, polarization)
  - The era of galaxy formation
    - Finding the early galaxies
    - Investigating and understanding local templates
  - Star formation
  - Structure of molecular clouds
  - Structure of active and normal galactic nuclei

Galaxy evolution in pictures



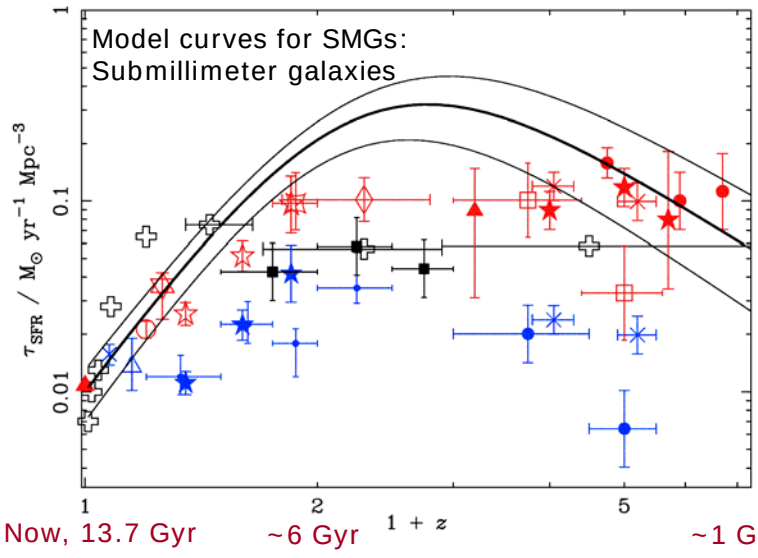


"Submillimeter galaxy" (SMG) properties

- "Invisible" at optical wavelengths: dusty galaxies
- Gas masses: few$\times 10^{10}$ $M_\odot$
- Luminosity: $10^{11.5}$ to $10^{13.5}$ $L_\odot$
- Some, somewhat less luminous and less massive, are gravitationally lensed
- Tend to lack strong X-ray emission, implying that the luminosity is largely from star formation rather than AGN
- Merger of large galaxies in an era of small mergers???

Hughes et al. 1998, Downes et al. 1999

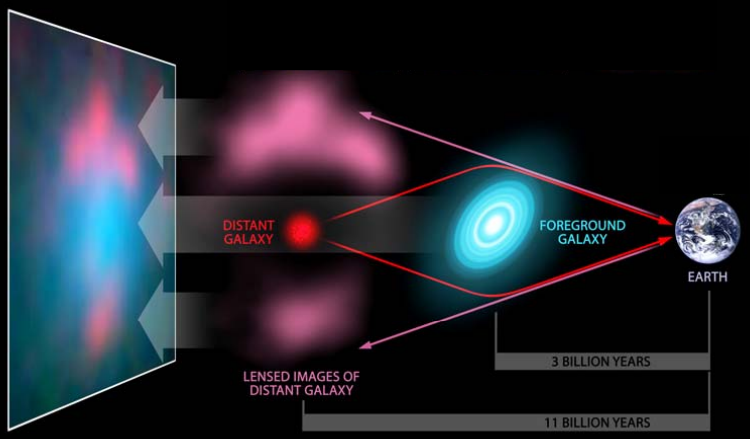
"Madau plot" of star formation rate density



Now, 13.7 Gyr ~6 Gyr ~1 Gyr

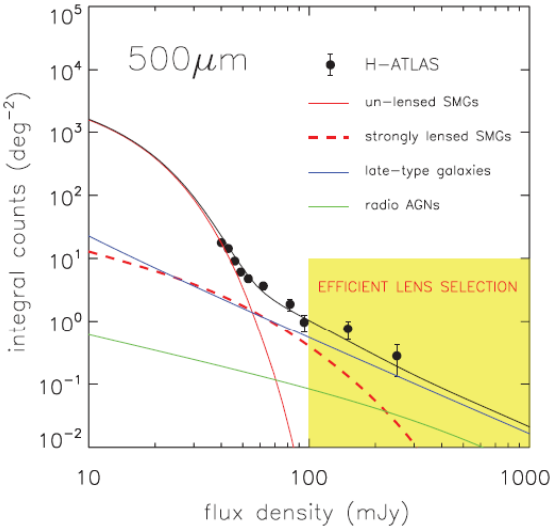
Blain 2004 (updated from Blain et al. 2002)

Lens geometry



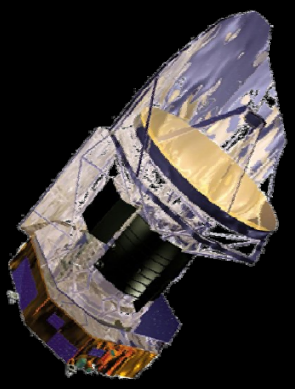
Typical magnification of known lenses is ~10

Galaxy-galaxy gravitational lenses select high-redshift galaxies



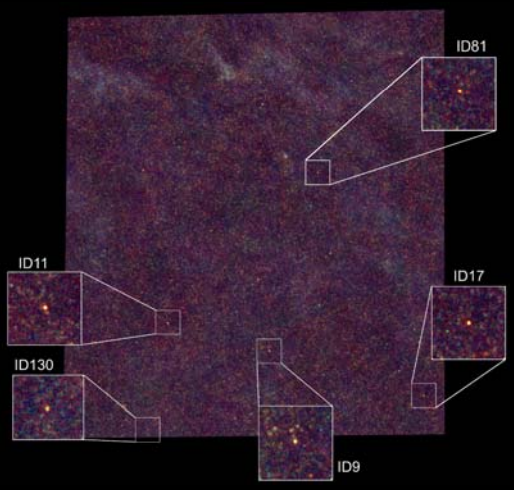
Negrello et al. 2010

H-ATLAS lensed galaxy candidates



Herschel Space Observatory

Pilbratt et al. 2010



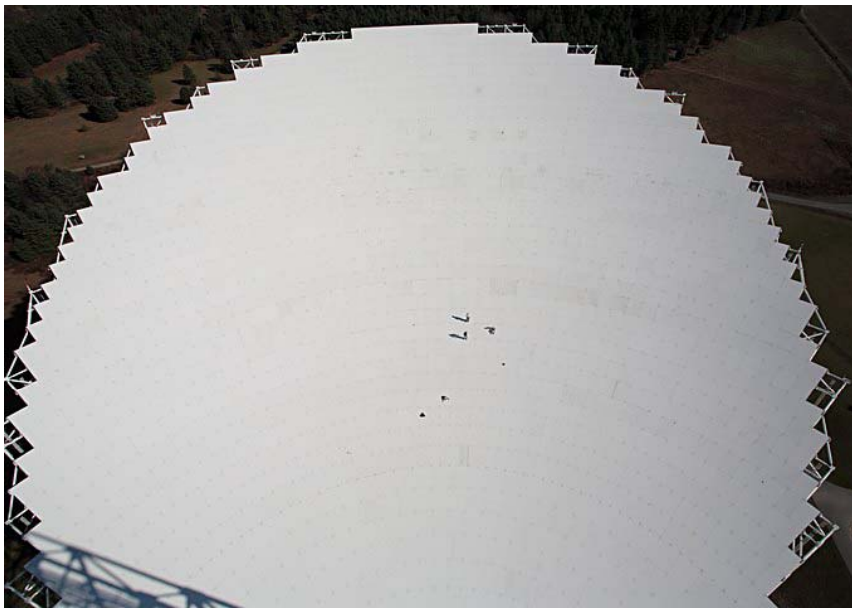
The Zpectrometer
ultrawideband correlation spectrometer

NSF ATI Program award AST-0503946 to UMD

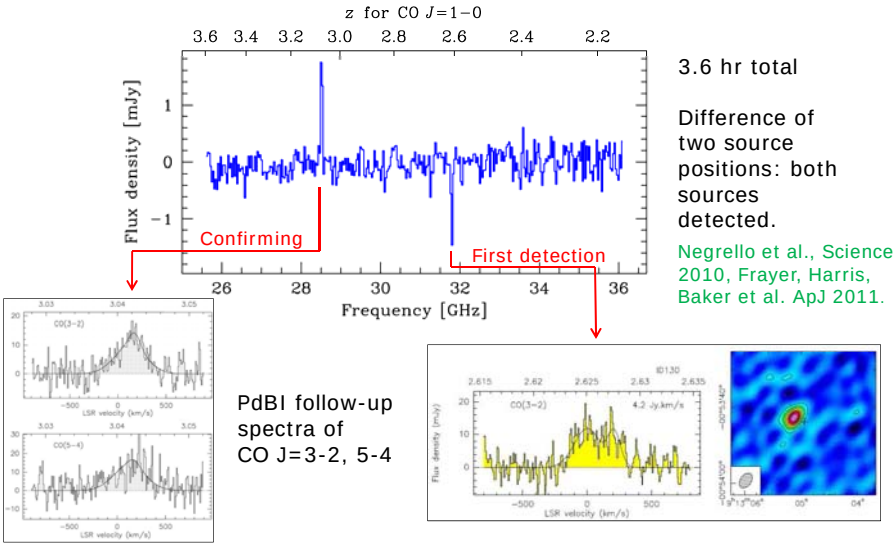
The 100 meter diameter Robert C. Byrd Green Bank Telescope (GBT)

UMD's Zpectrometer correlators on the GBT receiver turret

The view from the top



Zpectrometer detection of Herschel/SPIRE sources from H-ATLAS



3.6 hr total

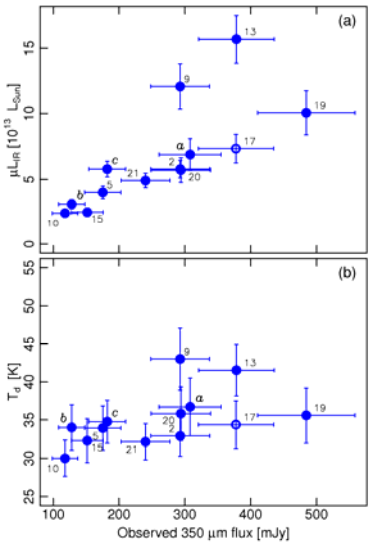
Difference of two source positions: both sources detected.

Negrello et al., Science 2010, Frayer, Harris, Baker et al. ApJ 2011.

PdBI follow-up spectra of CO J=3-2, 5-4

Herschel ATLAS: Eales et al., PASP 2010

Luminosity and dust temperatures vs. 350 μm flux density



Observed luminosity generally scales with 350 μm flux density

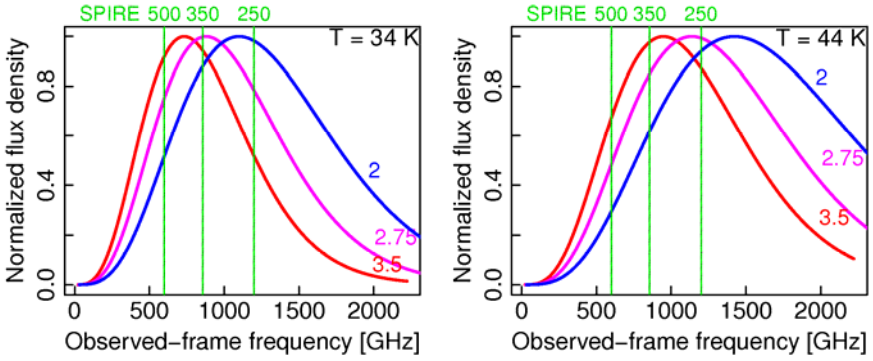
Most temperatures very similar, 34 ± 2 K, characteristic of classical SMGs

But: two high outlier points are from the two galaxies with z > 2.9, so selection effects are probably present

Harris et al. 2012

Temperature bias

- Selection as "350 μm peakers" biases sample to lower dust temperatures

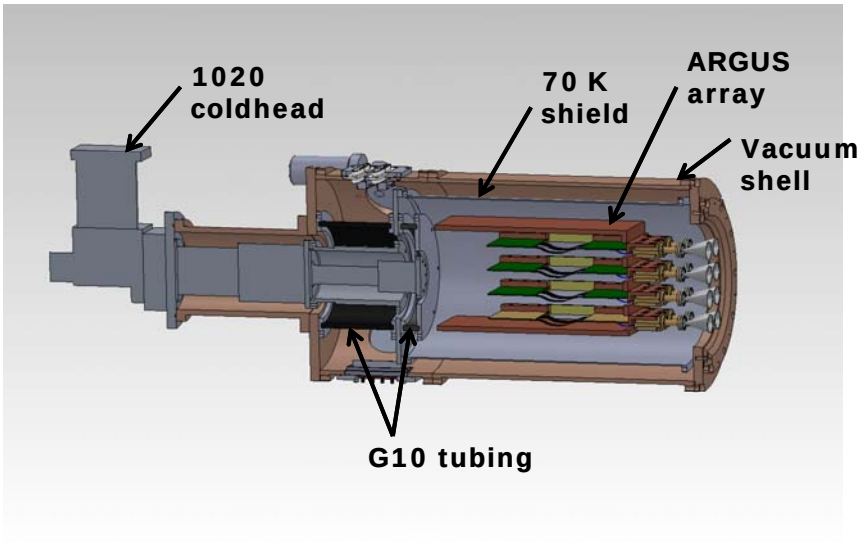


- Proposals submitted to expand selection

The Argus 4 mm focal plane camera for the GBT

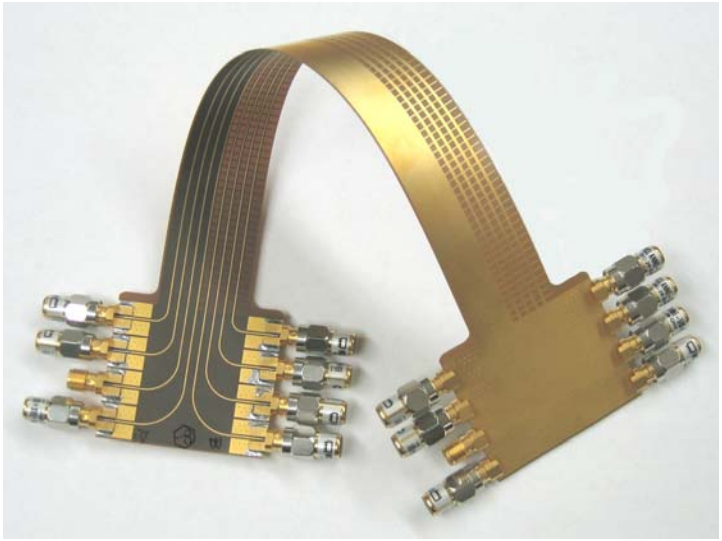
- Project start Sept. 2012
- 16-pixel radio camera for the GBT
- 7” resolution at HCN J = 1—0
  - Dense, star-forming gas in galaxies
  - Complements ALMA and CARMA with zero-spacing data (large-scale structure)
- Collaboration with Stanford, JPL/Caltech, Miami
- MD: Systems, microwave interconnects, electronics, calibration, astronomy

Cryostat and array, preliminary design



Courtesy J. Gunderson, U. Miami

Flexible printed microwave transmission lines for multiple pixels

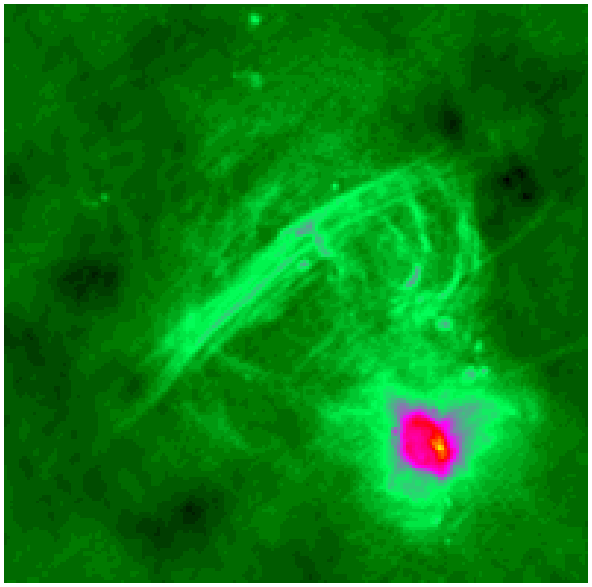


Harris et al. 2012

Herschel HEXGAL Galactic center program

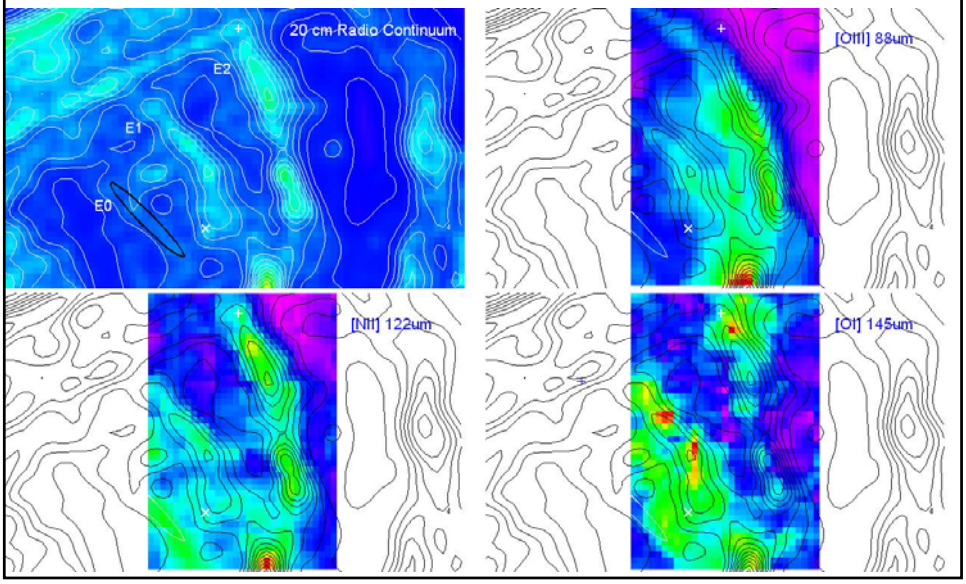
- What excites the gas deep in galactic nuclei?
- Where is which excitation mechanism most important in the Arches/Sickle region?
  - UV from hot stars
  - X-rays from sources in GC
  - Shocks from WR winds
  - Ambipolar diffusion with strong magnetic fields
- What is the connection between the thermal and nonthermal filaments?

Galactic Center in radio continuum



VLA image

Thermal Arches – Overview



Potential projects

- GBT/Zpectrometer and CARMA (observing, radiative transfer; with many others)
- Herschel HIFI and SOFIA Galactic center (data analysis, astronomy; with MPIfR Bonn, UCLA, Cornell)
- Focal plane array development for GBT, dense gas mapping at 4 mm wavelength (electronics, microwave, astronomy; with Stanford, Caltech, JPL, Miami)