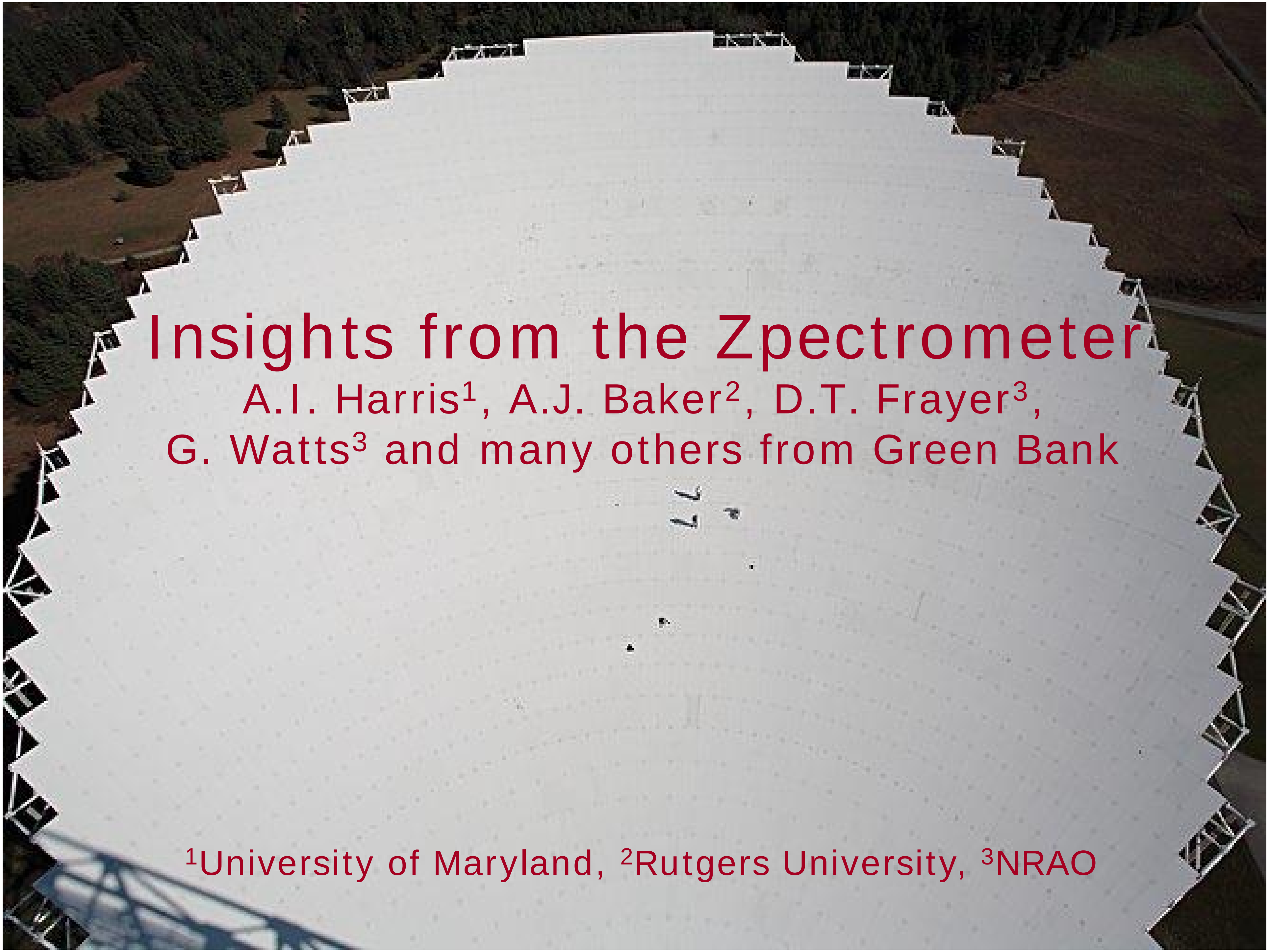


Insights from the Zpectrometer

A.I. Harris[1], A.J. Baker[2], D.T. Frayer[3],
G. Watts[3] and many others from Green Bank

[1]University of Maryland, [2]Rutgers University, [3]NRAO

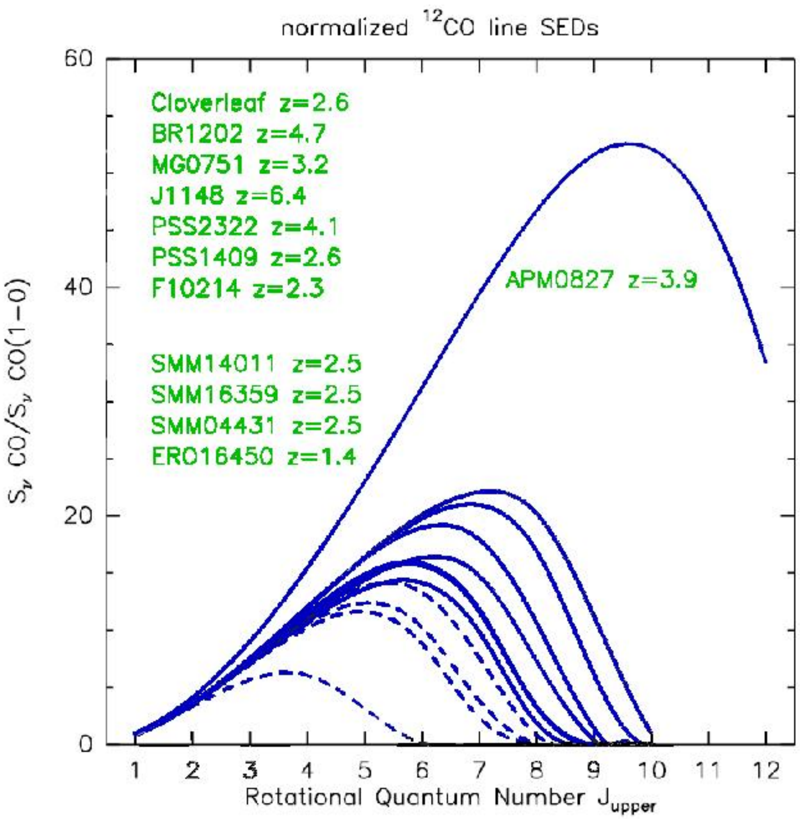
The Zpectrometer

A collaboration between UMD (spectrometer) and NRAO (receiver)
NSF ATI Program award AST-0503946 to UMD

Zpectrometer correlators on the GBT receiver turret

- Ultra-wideband spectrometer for use with the GBT's facility Ka-band receiver
- Bandwidth of 25.6 to 37.7 GHz covers z = 2.1 to 3.5 in CO J = 1−0 (other redshifts in other transitions): line searches
- Cross-correlation architecture is designed to produce high stability for long integrations: weak lines

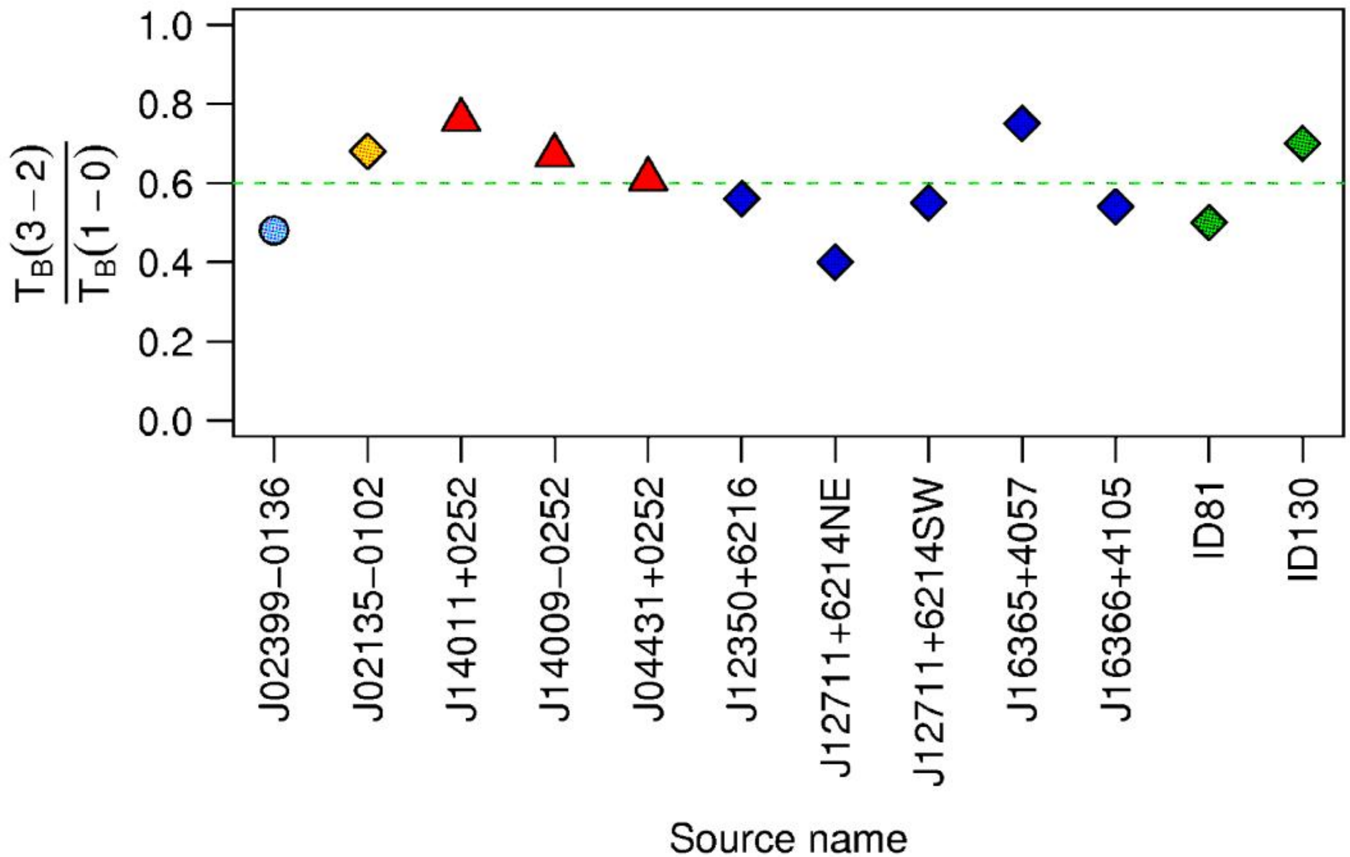
CO excitation and gas mass



"CO SED" summary from cover of 2006 NA ALMA/NRAO meeting (Weiss et al. 2007)

- Mid-J line studies had suggested a single gas component with moderate excitation.
- J = 1-0 is difficult to measure: ~30 GHz, low flux.
- It is key for empirical mass conversion prescription $M_{gas} = \alpha\ L'_{CO(1-0)}$, α derived from local ULIRGS. (see e.g. Solomon & Vanden Bout 2005)
- Is gas thermalized and thick so $L'_{CO(mid-J)} = L'_{CO(1-0)}$?
- How well can we get masses, SF efficiency, etc?

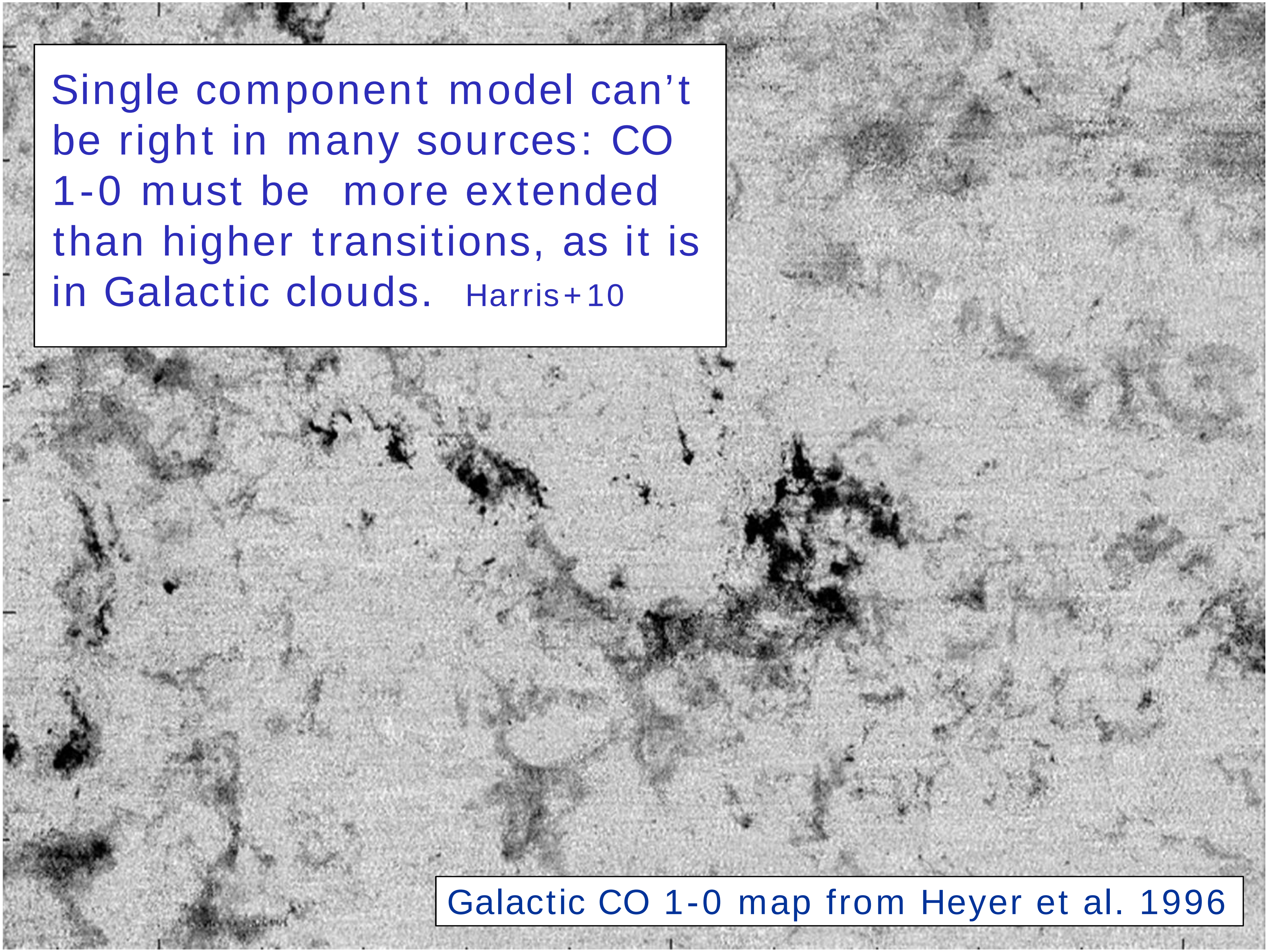
Excitation in high redshift sources: L'(J =3—2) < L'(J =1—0)



Ivison+10, Swinbank+10, Harris+10, Ivison+11, Frayer+11

But not always: QSOs may be an exception with L'(3-2) ≈ L'(1-0)   e.g. Riechers et al. 2011

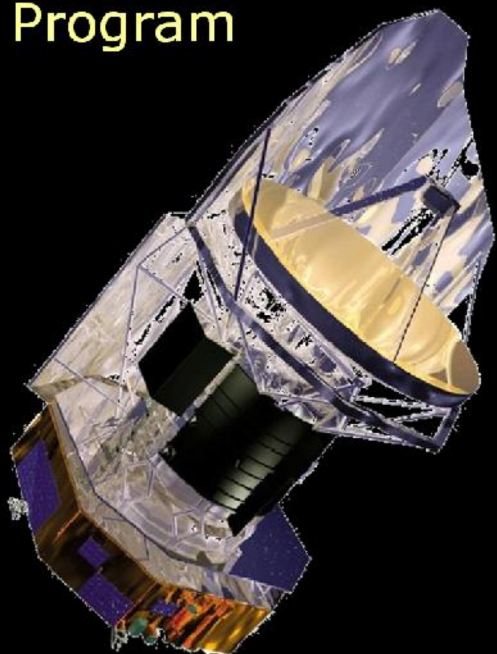
Single component model can’t be right in many sources: CO 1-0 must be more extended than higher transitions, as it is in Galactic clouds. Harris+10

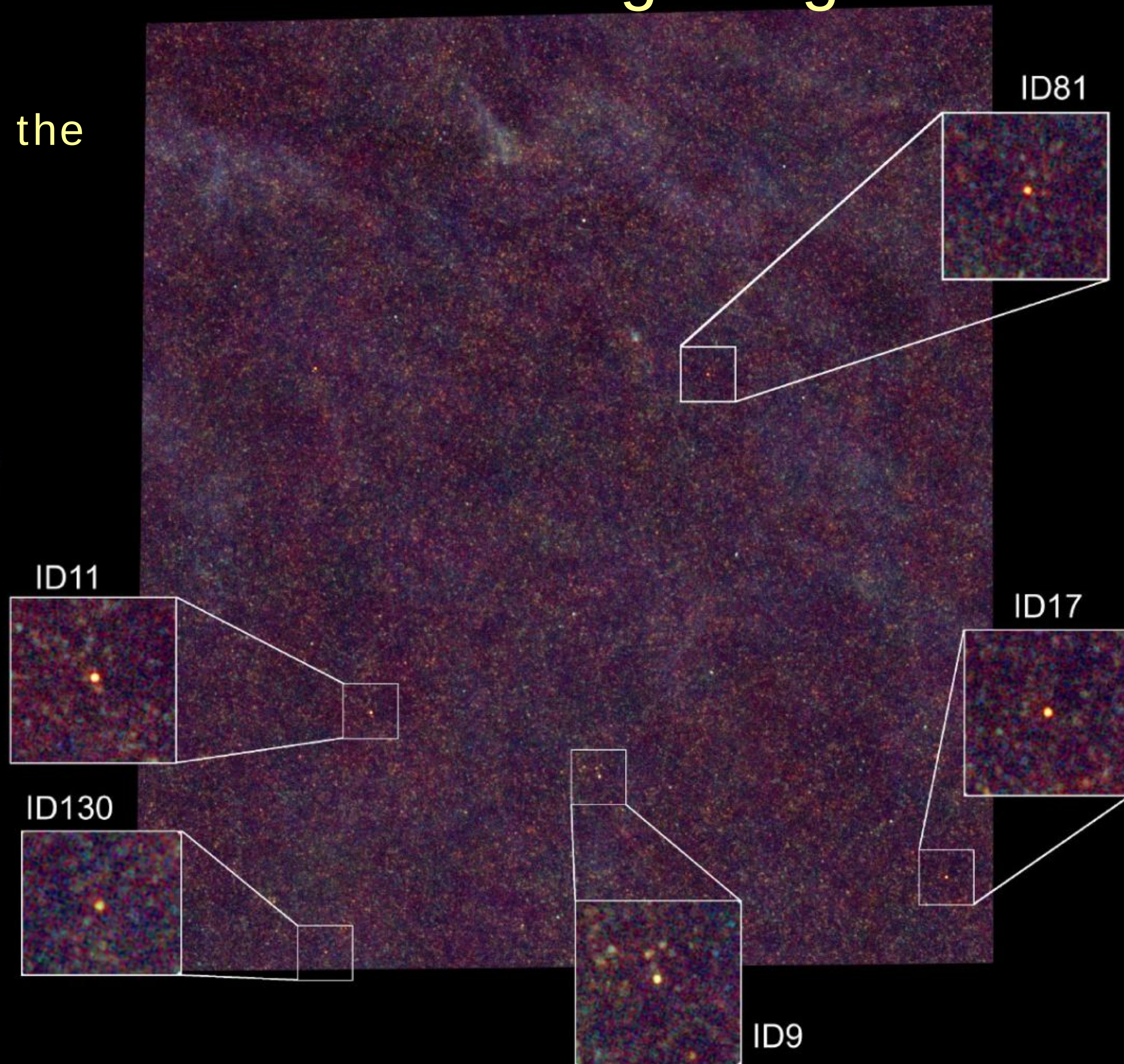


Galactic CO 1-0 map from Heyer et al. 1996

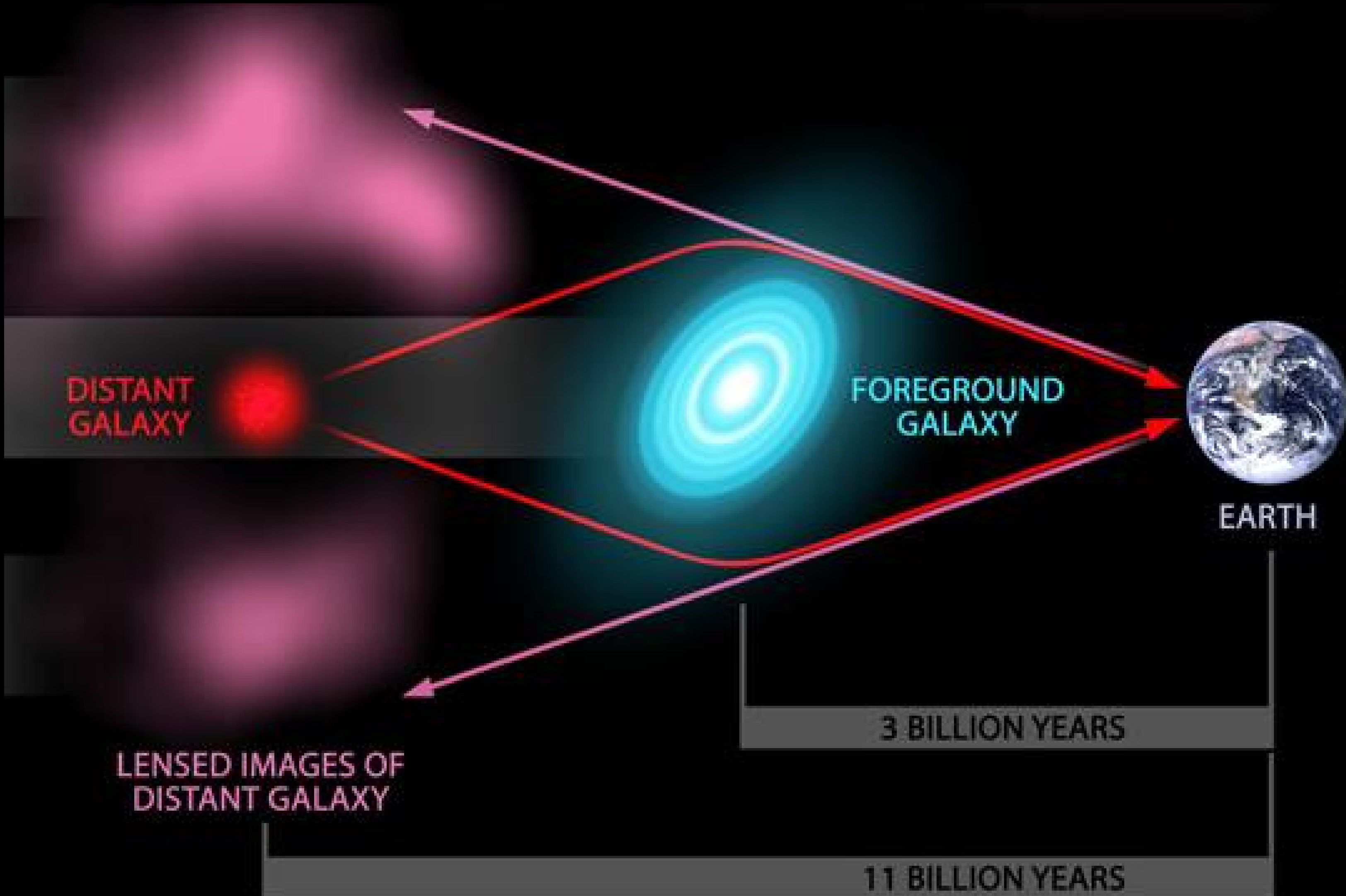
Herschel-ATLAS identifies high-z galaxies

SPIRE image from the Herschel Science Demonstration Program

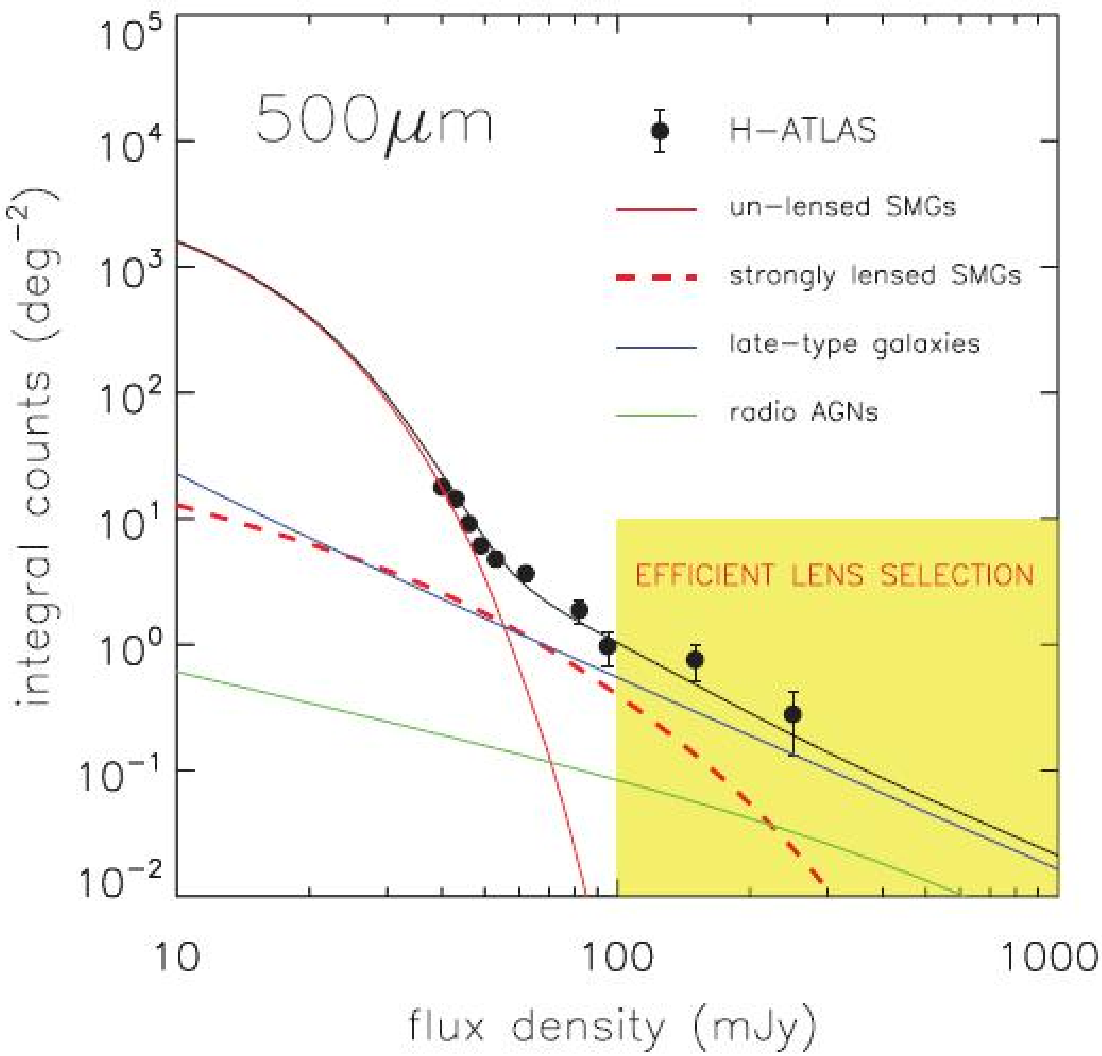




Lens geometry

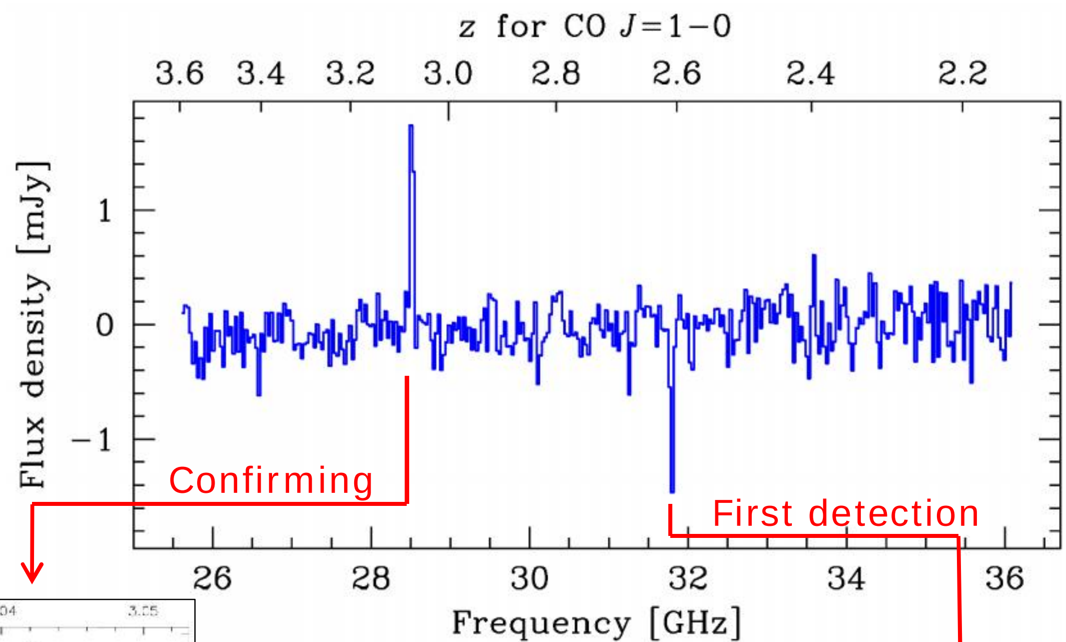


Galaxy-galaxy gravitational lenses select high-redshift galaxies



Negrello et al. 2010

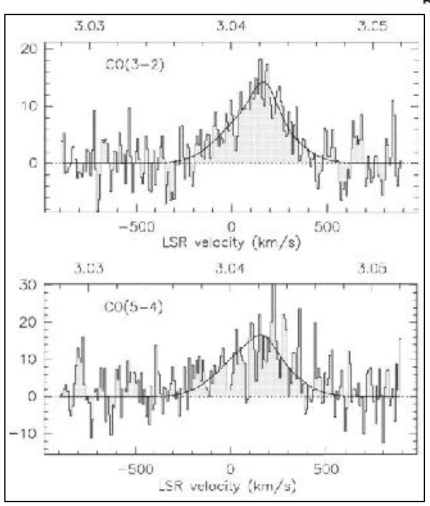
Zpectrometer detection of Herschel/SPIRE sources from H-ATLAS



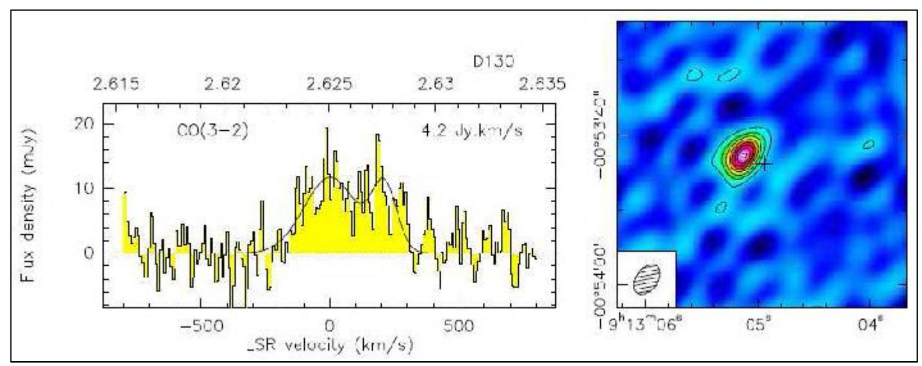
3.6 hr total

Difference of two source positions: both sources detected.

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

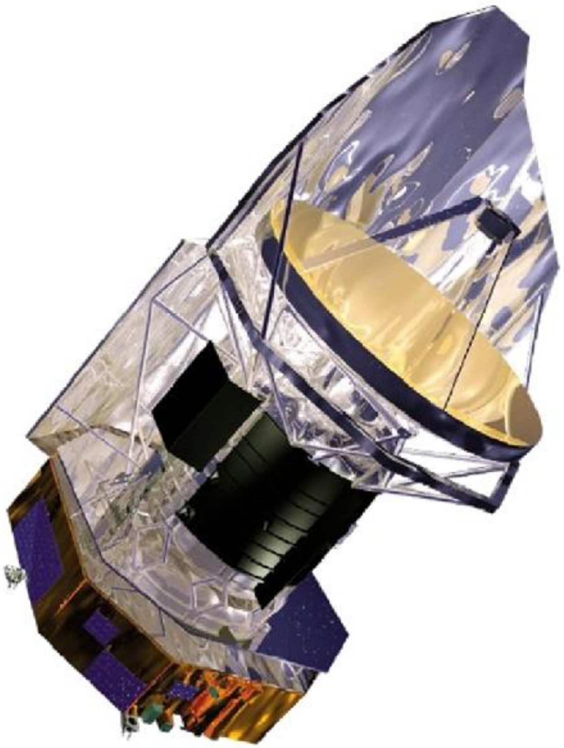


PdBI follow-up spectra of CO J=3-2, 5-4



Herschel ATLAS: Eales et al., PASP 2010

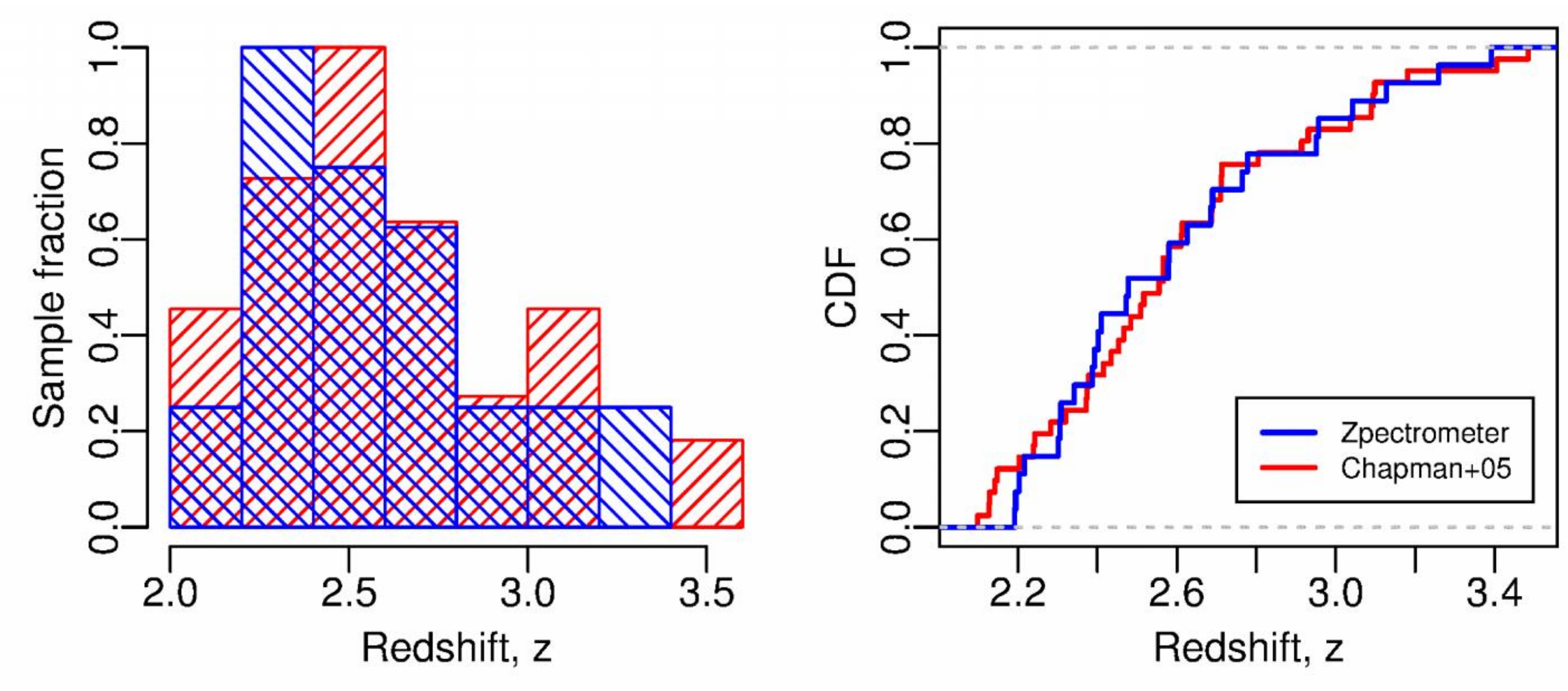
CO 1—0 from the Herschel-ATLAS and Hermes surveys



Herschel Space Observatory
Pilbratt et al. 2010

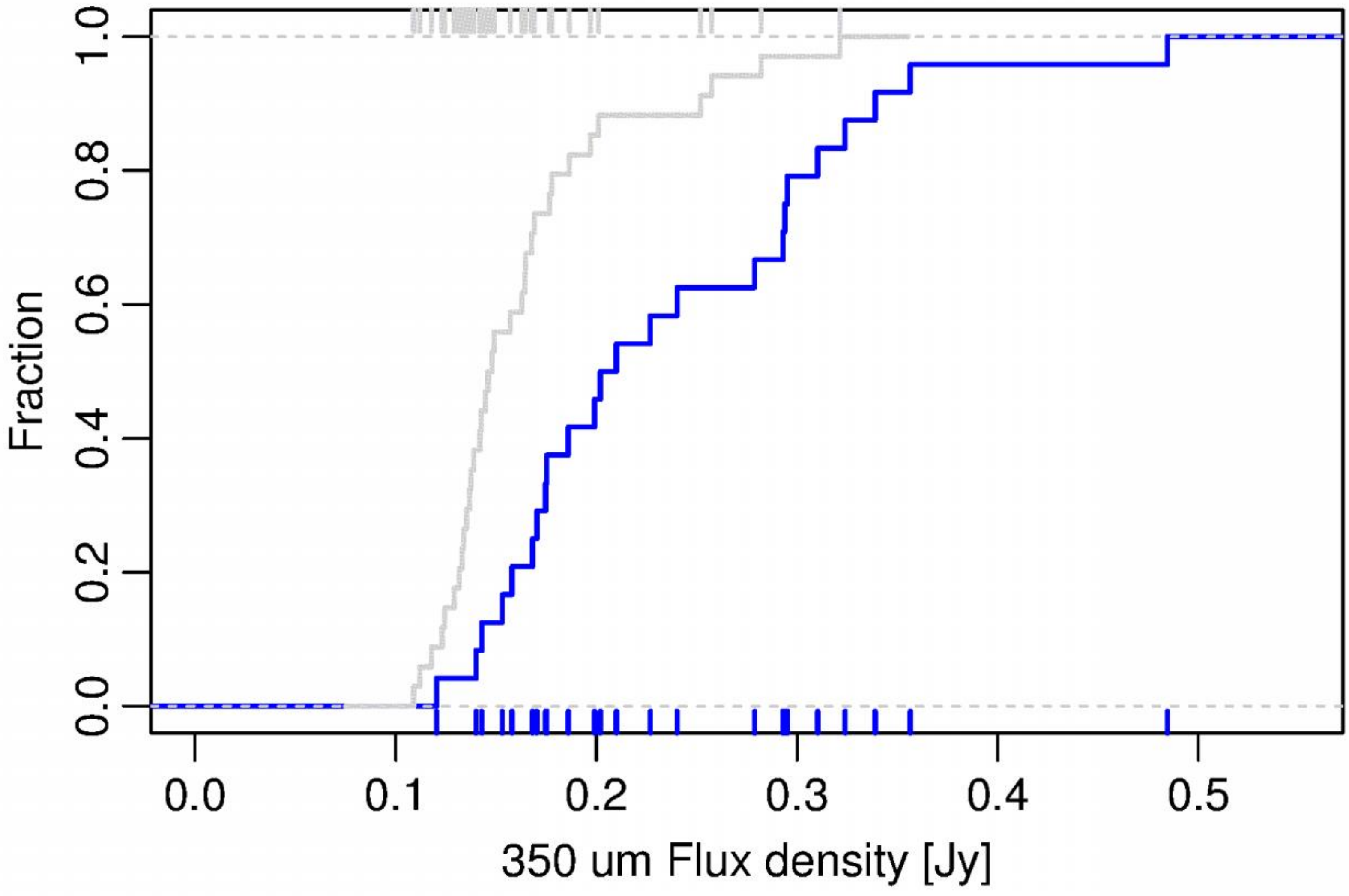
- Targets from SPIRE photometry at 250, 350, and 500 μm (Eales+10, Griffin+10): "350 micron peakers"
- 58 sources, 24 detections, 34 nondetections
- Expect gravitationally lensed sources (Negrello+10)
- Statistical correction for gravitational amplification: typical amplification is 10 (Harris+12)

Redshift distribution

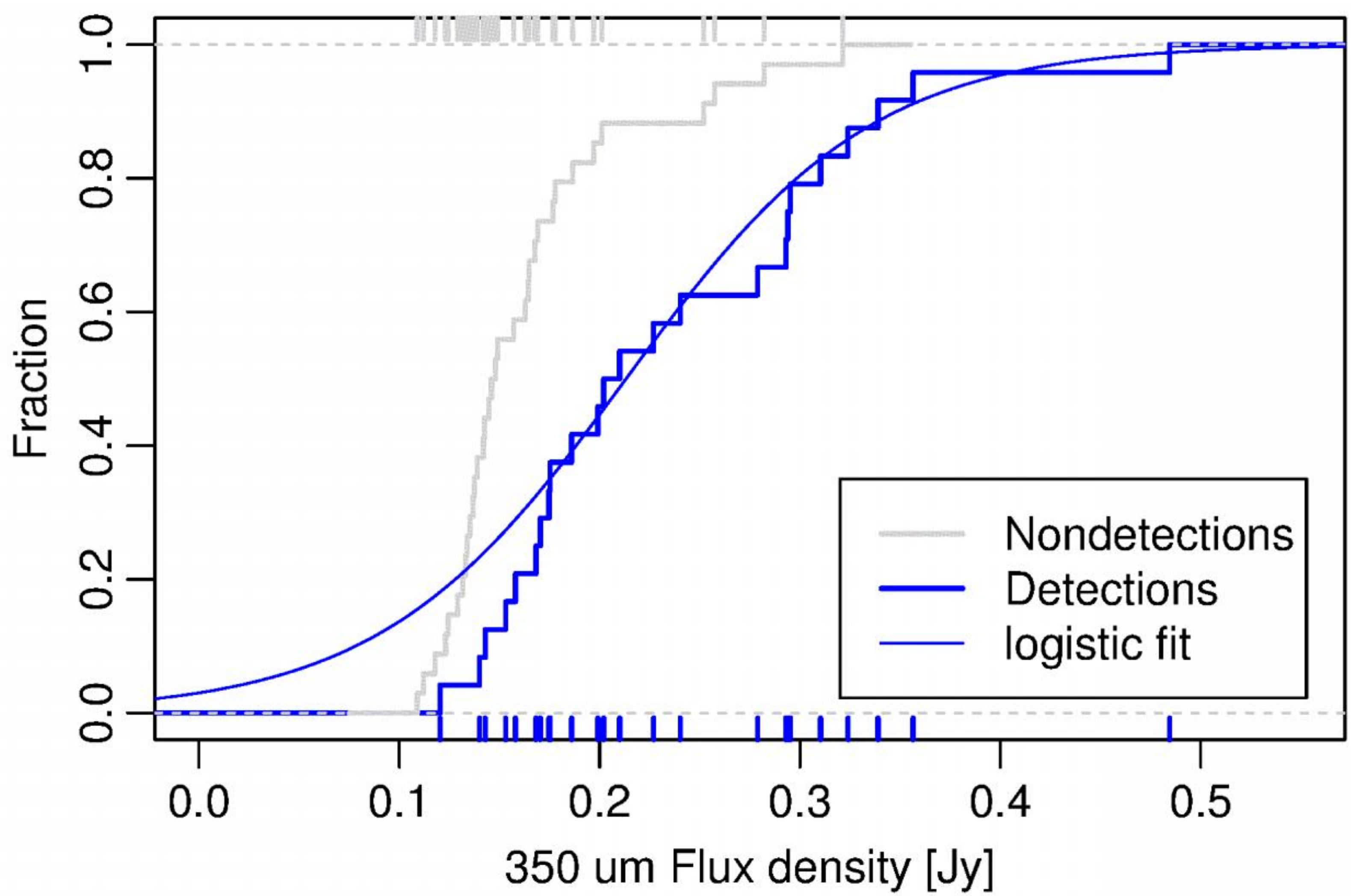


The Zpectrometer (Herschel 350µm+GBT) and Chapman+05 (SCUBA 850µm+VLA+Keck) samples share the same redshift distribution: the classic “SMG” population.

Detections and non-detections vs. 350μm flux density

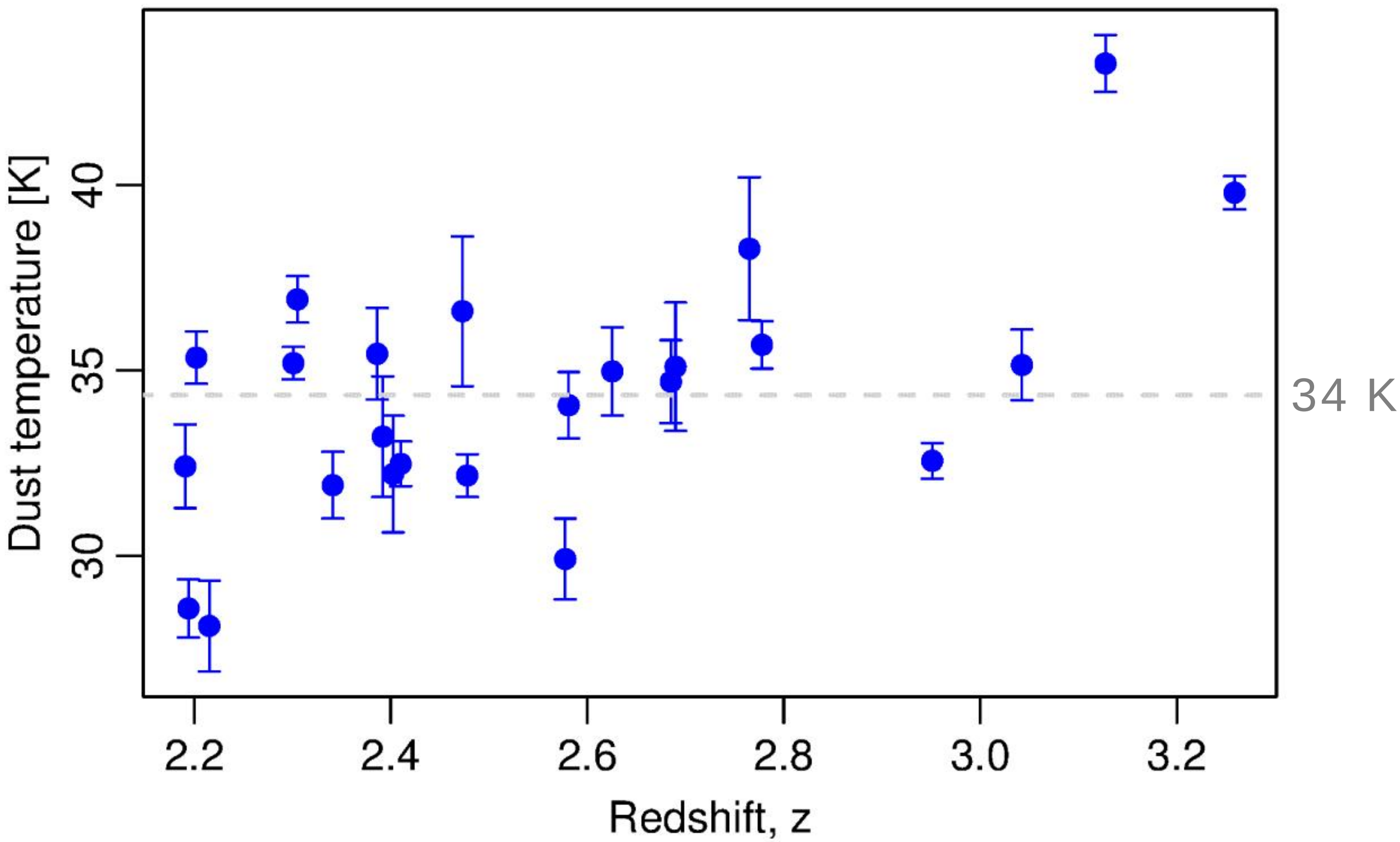


Detections and non-detections vs. 350μm flux density



Dust temperature vs. z

Wien's law: $a_{\text{peak, rest}} T_d = \dfrac{a_{\text{peak, obs}}}{1+z} T_d = \text{constant}$



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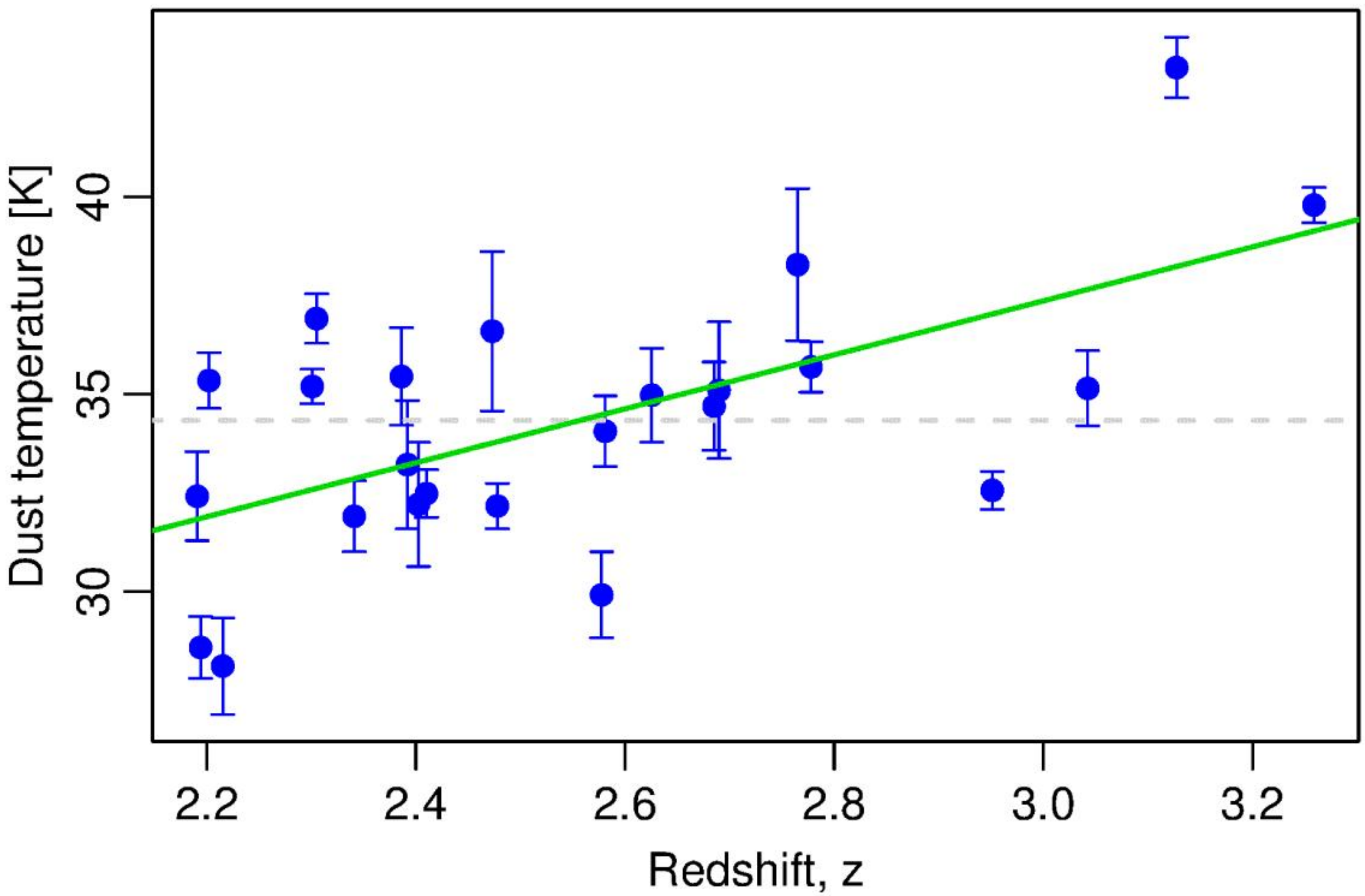
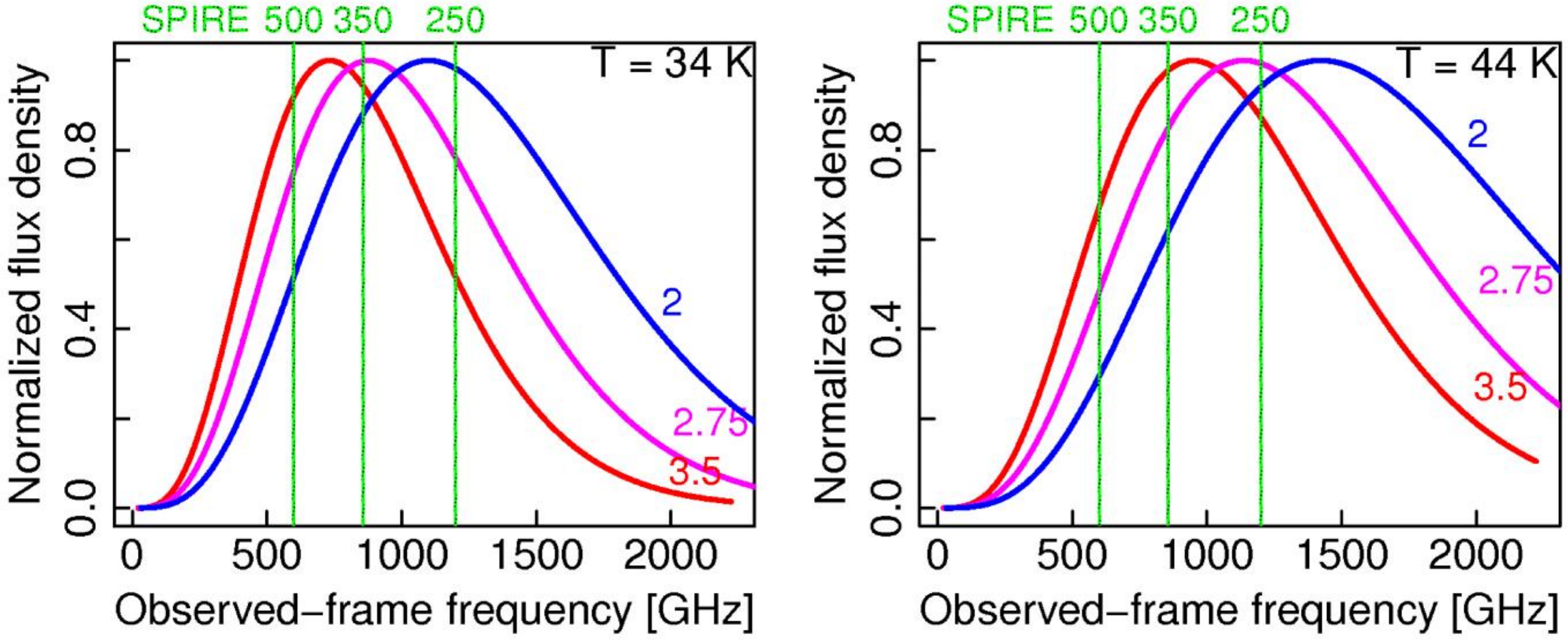
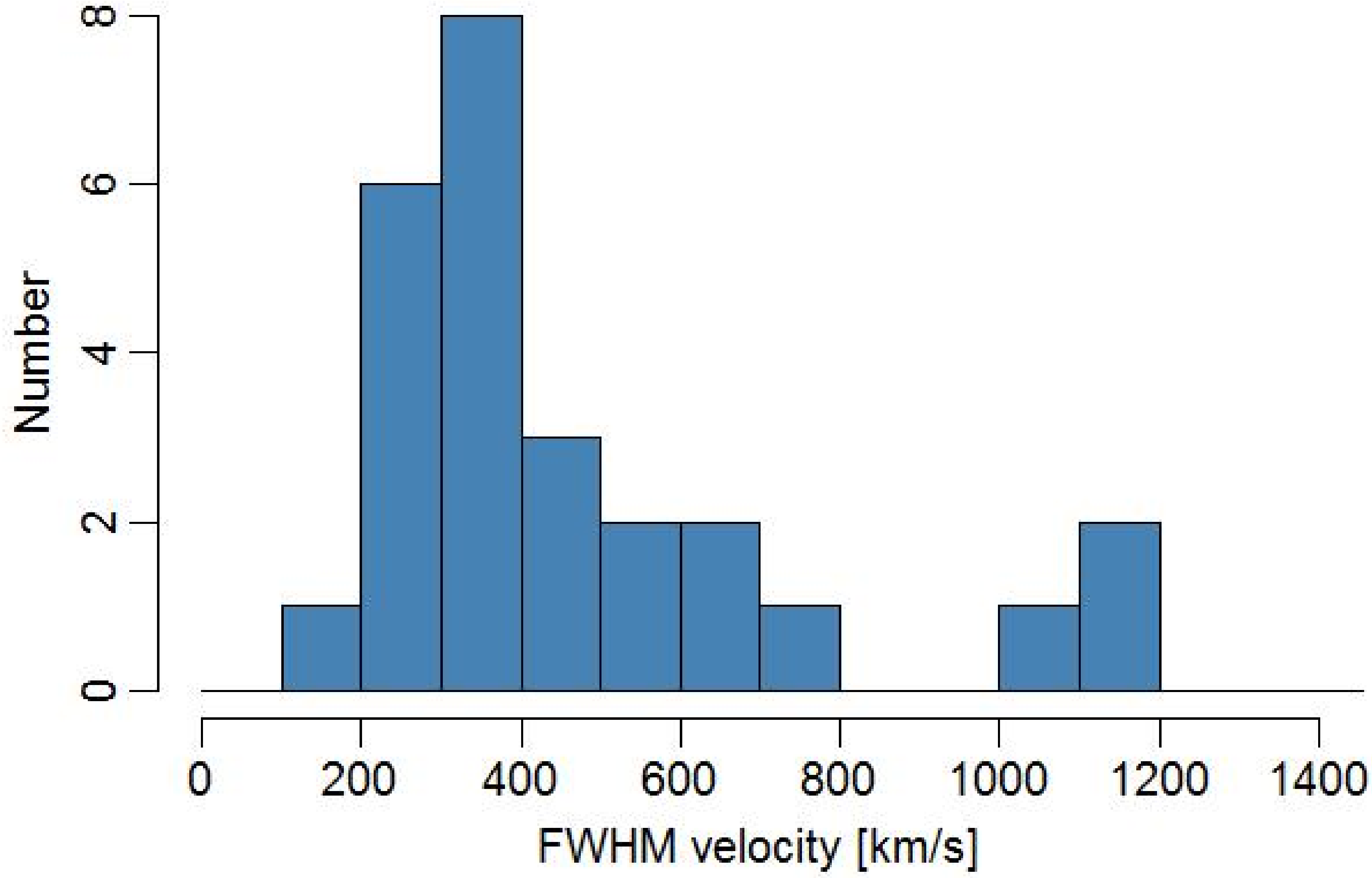


Temperature bias

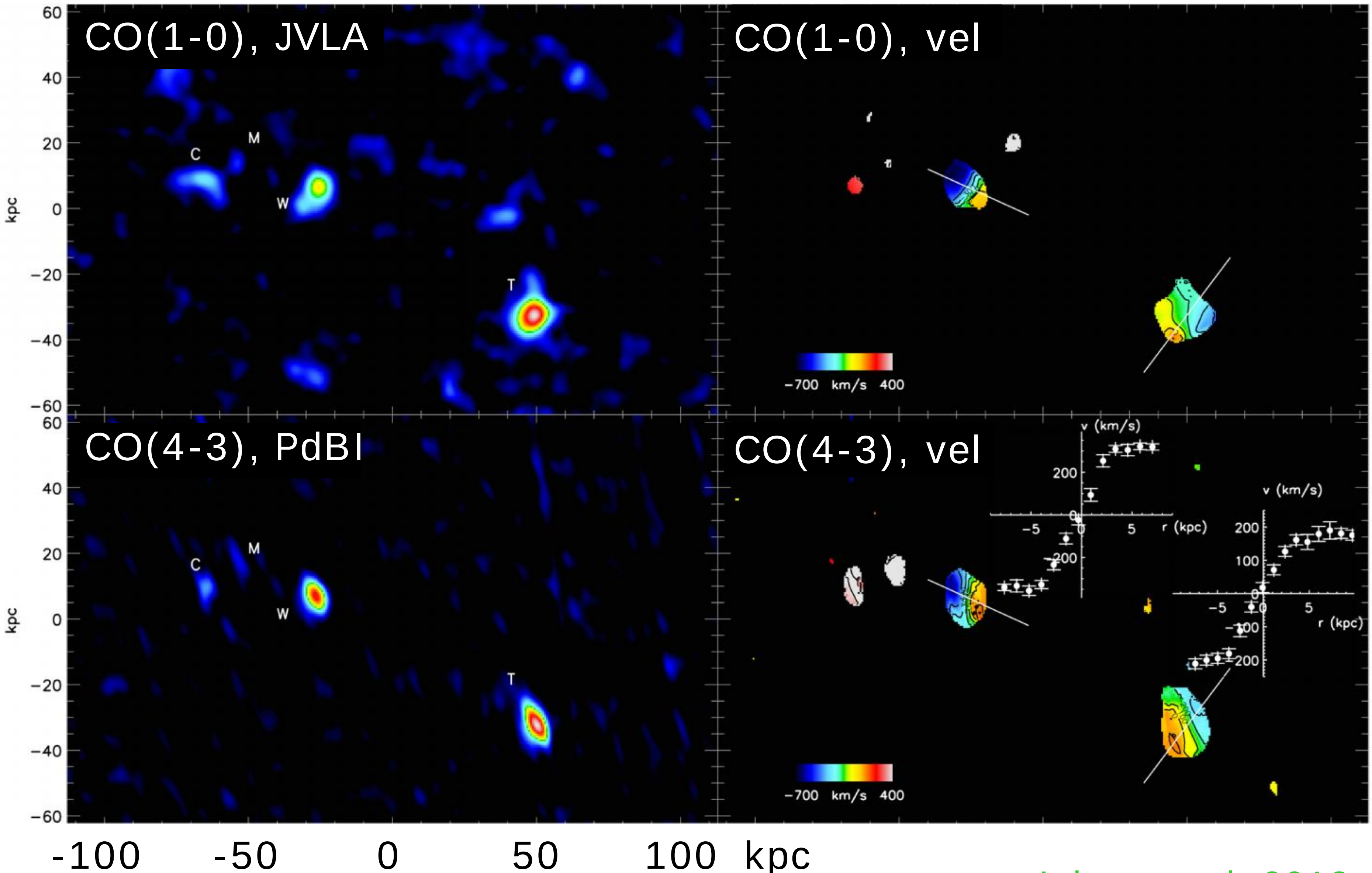
- Selection as “350 μm peakers” biases sample to lower dust temperatures



Extreme widths identify extreme systems



CO imaging: a cluster of galaxies



Ivison et al. 2013

University-NRAO collaboration

- $520k NSF grant to UMD in 2005
- ~60 proposals, ~30 unique PIs
- Student, postdoc, faculty, staff involvement at UMD, Rutgers, NRAO, Hopkins, and elsewhere
- 18 publications with a substantial Zpectrometer component
  - 2 Nature, 1 Science, 13 ApJ, 2 MNRAS
  - 914 citations
- Targets for VLA, PdBI, 30m studies
- Explored and demonstrated correlation spectroscopy
- New signal processing techniques for line searches
- Identified problems with, and improved, the Ka-band receiver

Summary

- Very efficient targeted line searches in CO 1-0 with the GBT/Zpectrometer
- Nailed down the CO 1-0 intensity in DSFGs, indicating extended emission and changing gas mass estimates
- Analysis of nondetections and trend of dust temperature with redshift points to population of DSFGs more excited than the classic SMGs
- Statistical study shows that typical amplification of lensed galaxies from Herschel/SPIRE is 10, range of factor 2
- Provided redshifts for follow-on studies of multiple lines and higher spatial resolution
- Relatively low-cost instrument with broad community use