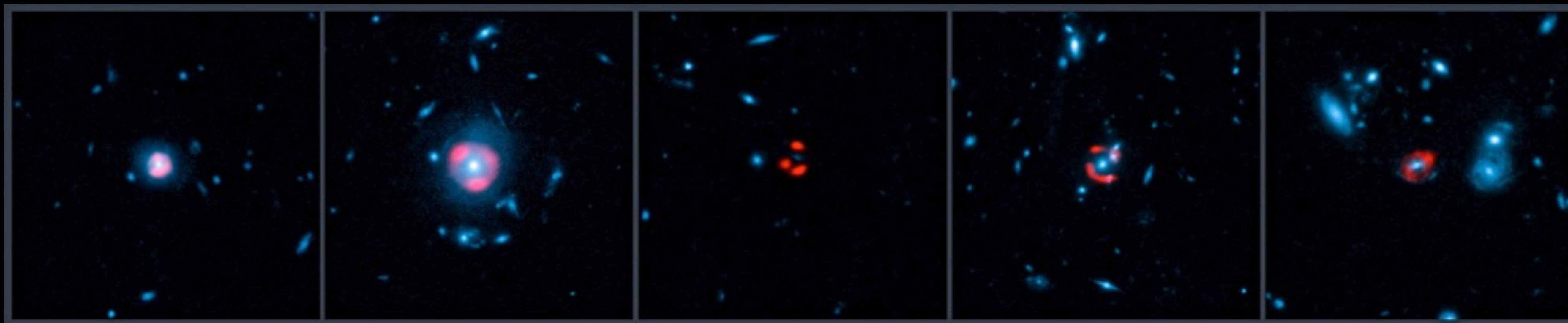
SPTxDES for lensed dusty galaxies



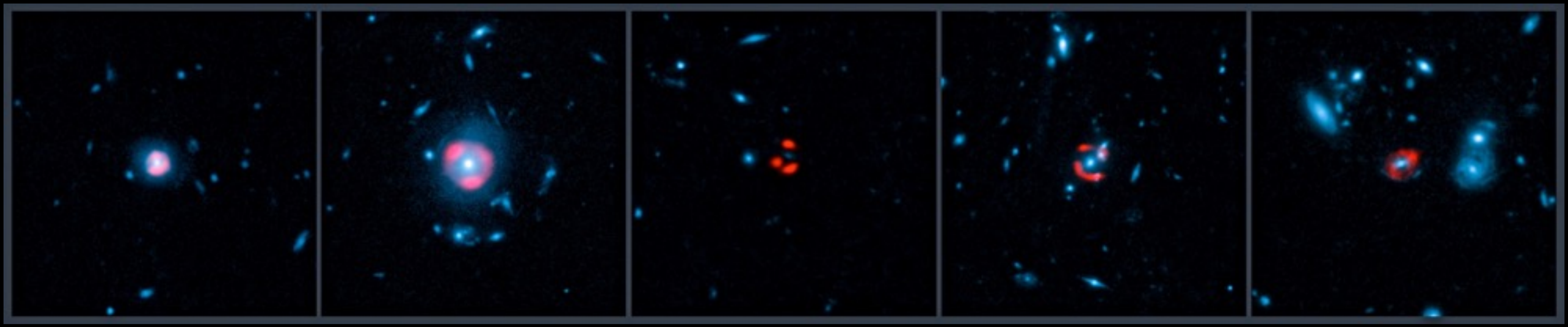
Joaquin Vieira

University of Illinois at Urbana-Champaign

Argonne Illinois DES Meeting

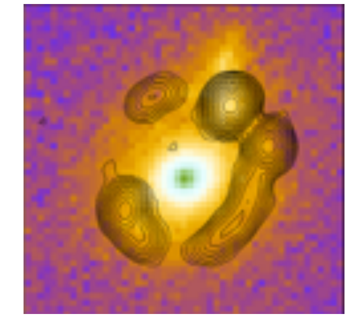
08 Dec 2014

Points to take home



- Dust is important for the study of galaxy evolution:
    - half of all energy produced since the big bang has been reprocessed by dust
    - enables us to detect galaxies independent (!) of redshift
    - dust is part of the rich chemistry in the interstellar medium that leads to life
- We are in a golden age of studies of the dust-obscured universe —> *Spitzer*, *Herschel*, *Planck*, SPT, ALMA, JWST, CCAT(?)
- Large samples of high-redshift, strongly-lensed galaxies have been uncovered by SPT, *Herschel*, and soon *Planck*. The selection is based solely on *flux*. (!)
- Strong gravitational lensing provides us with a cosmic magnifying glass to study galaxies in great detail.
- We can select more background sources in SPT by using a prior of the foreground lens from DES to dig into the noise. Naively, could find ~1000 lensed sources.

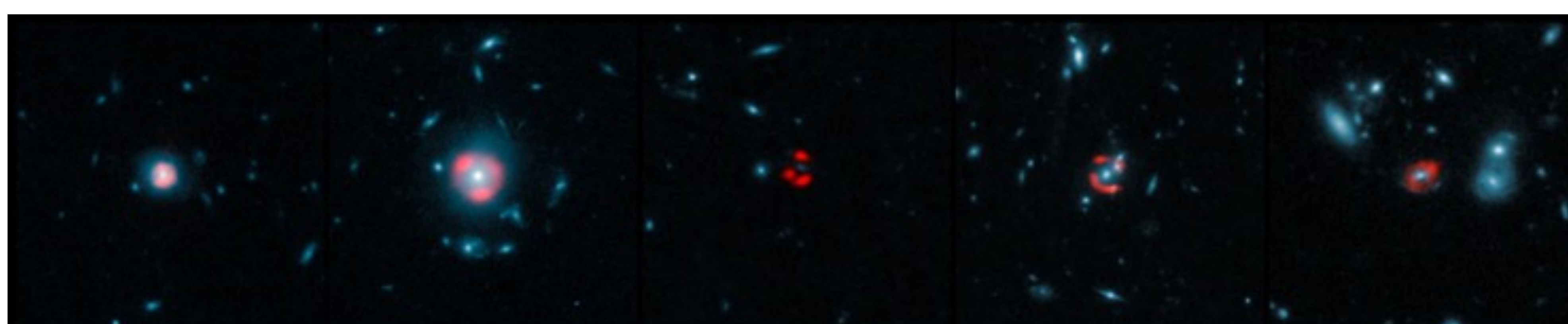
How to find lensed sources:



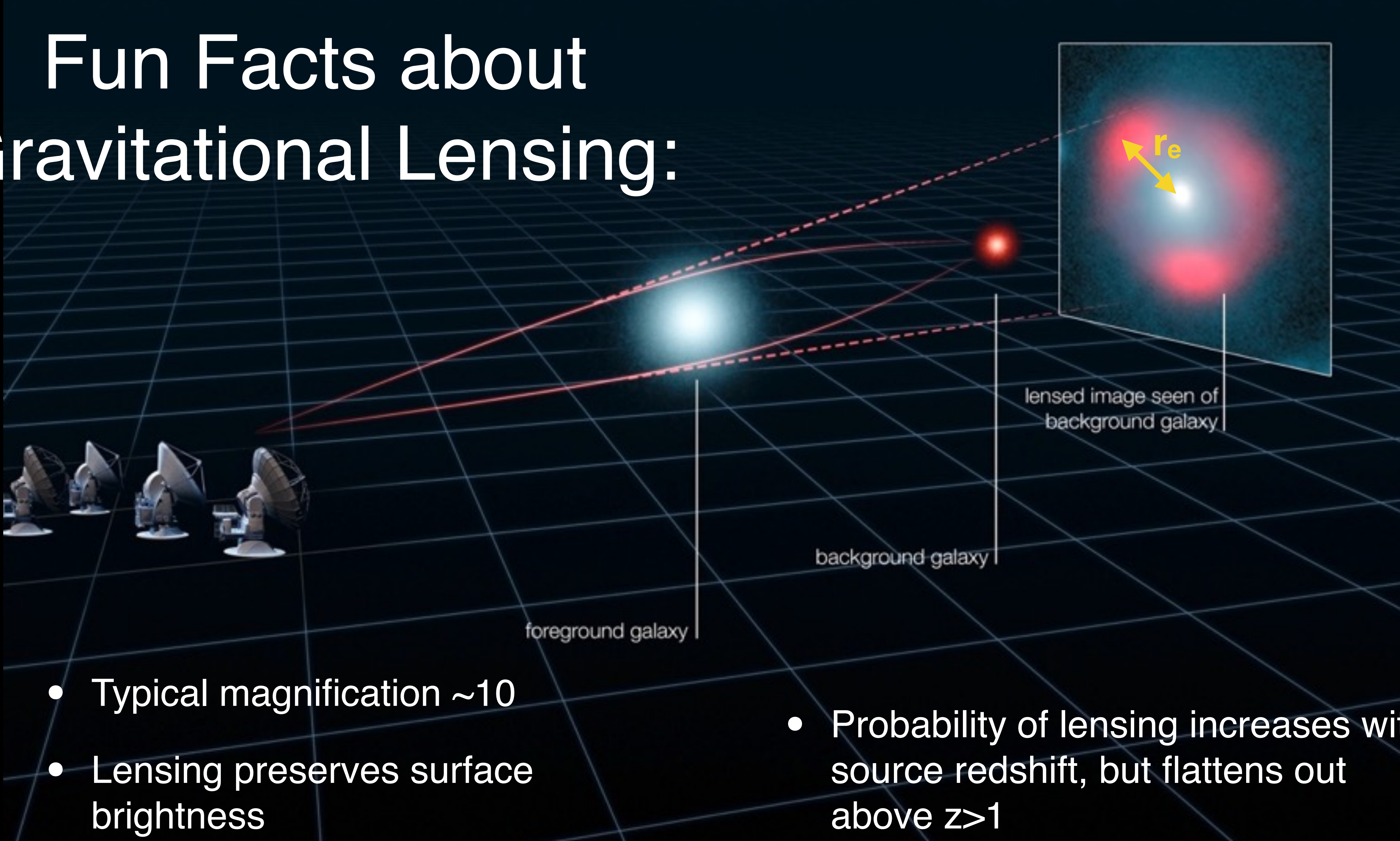
- **Radio** mid 90's: (e.g. CLASS) select flat spectrum sources, followup with high resolution radio.
- **Clusters** late 90's--today: (e.g. CLASH, HLS) Target massive clusters of galaxies in optical and/or submm.

- **Optical** 00's: (e.g. SLACS) Use large spectroscopic surveys to sift through millions of spectra, find lensed candidates, and followup with HST ... or just sift through thousands of images by eye.

- **sub/mm** 2010's: (e.g. SPT, Herschel/SPIRE) Survey large areas of sky in the submm and find the rare, bright sources.

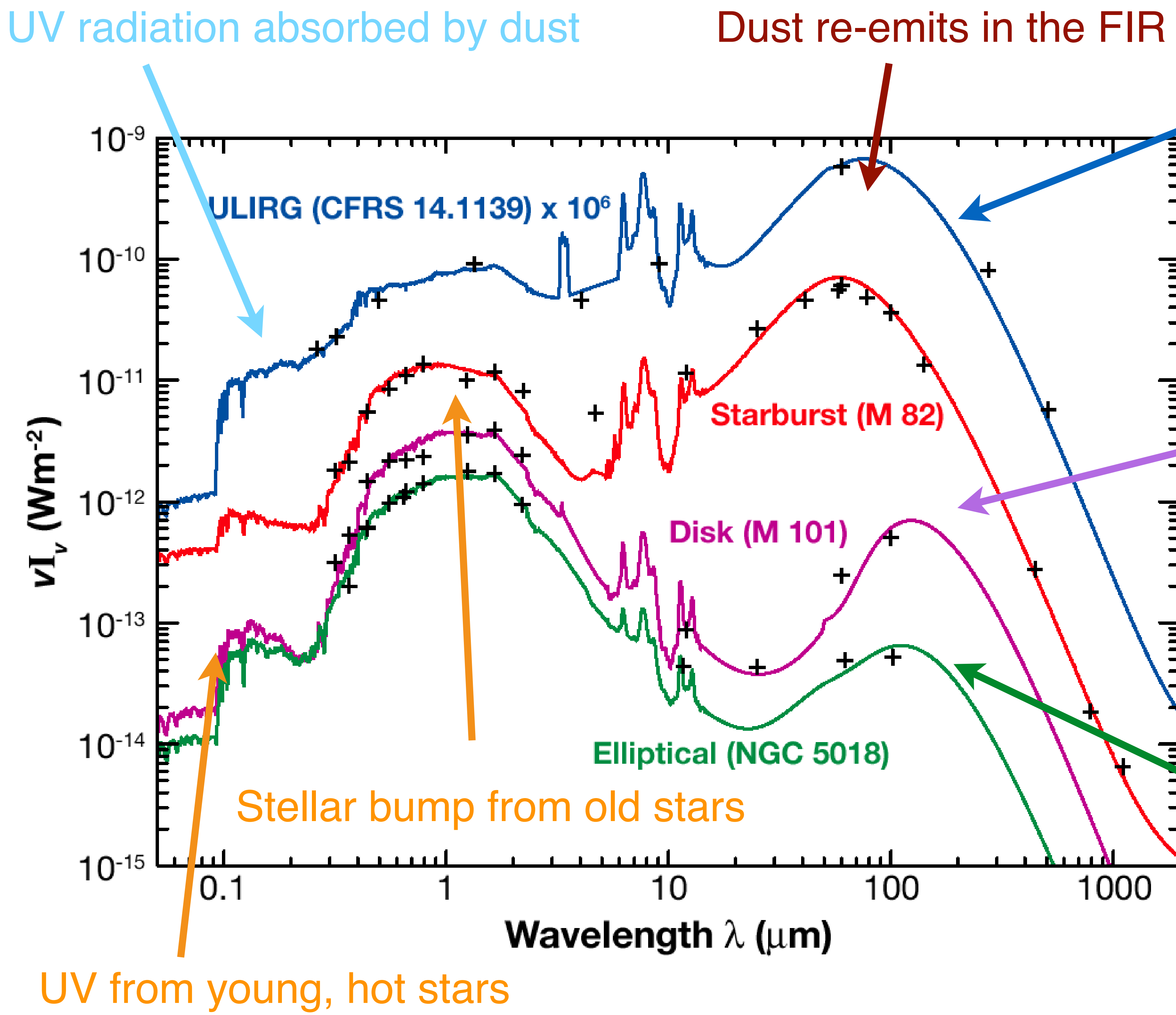


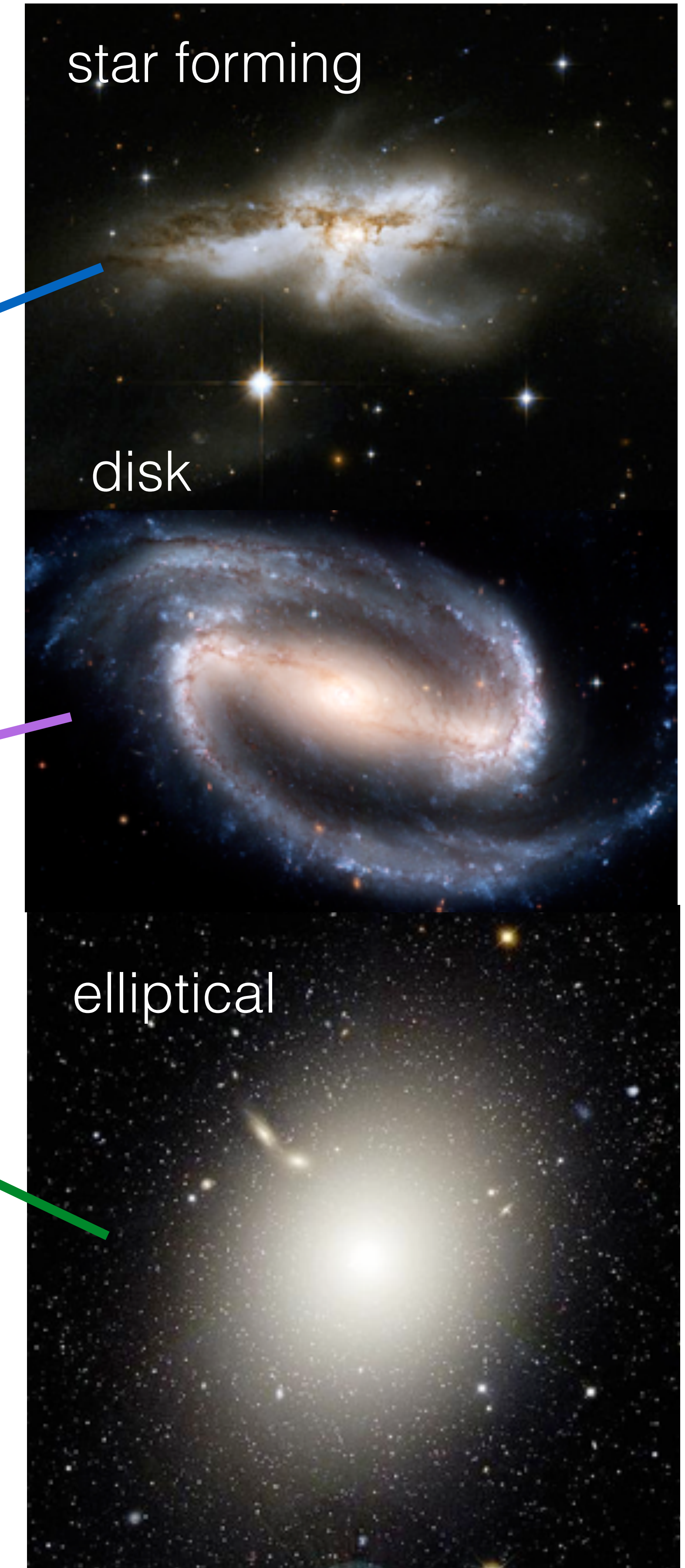
Fun Facts about Gravitational Lensing:



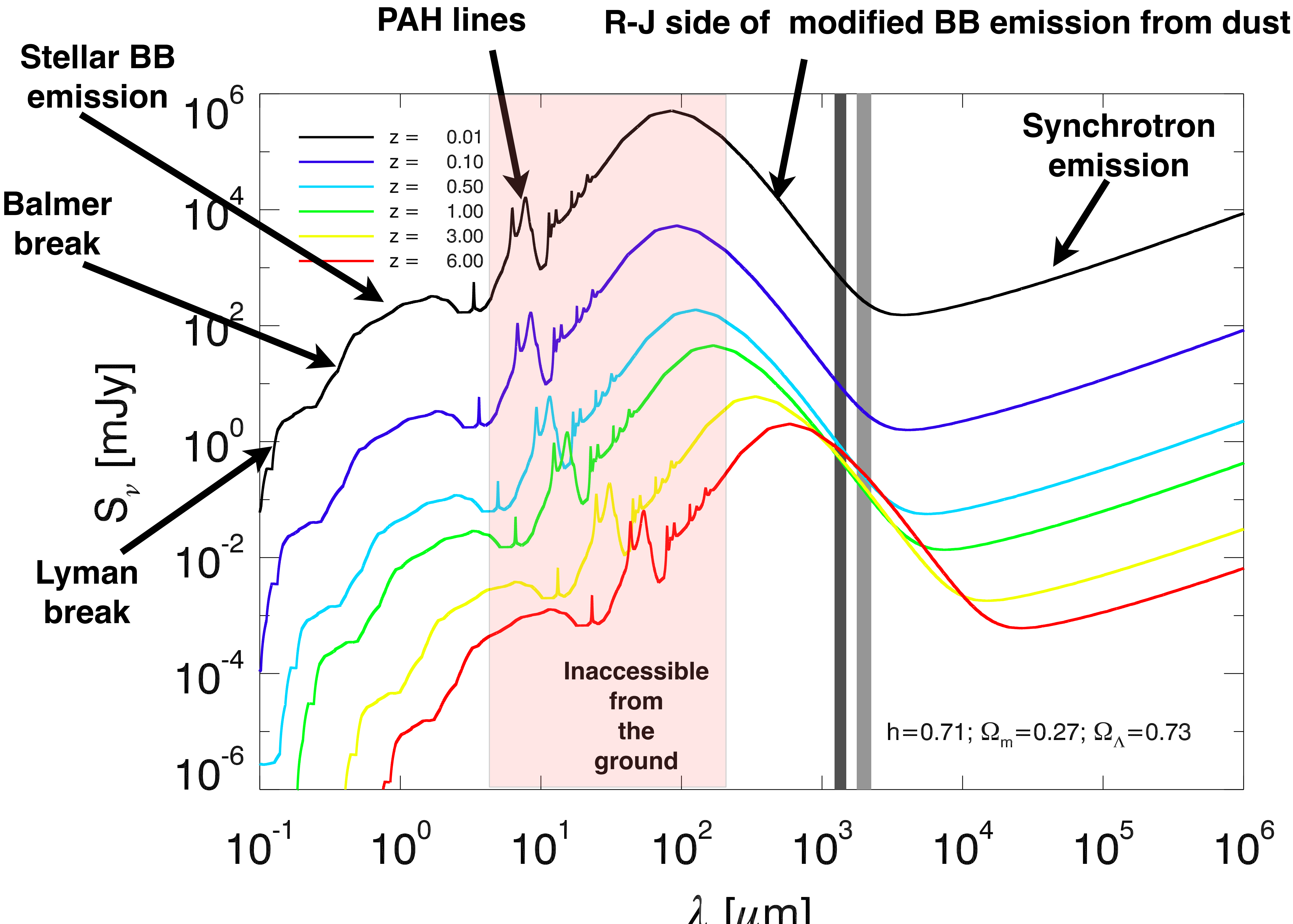
- Typical magnification ~10
- Lensing preserves surface brightness
- Lensing is achromatic
- Measure an Einstein radius and you have measured the mass
- The lensing mass is ~1/2 DM and ~1/2 baryons
- Probability of lensing increases with source redshift, but flattens out above z>1
- cluster = larger cross section ; galaxy = more opportunities for lensing
- ~1/200 massive early-type galaxies is a strong lens

Spectral Energy Densities of Galaxies

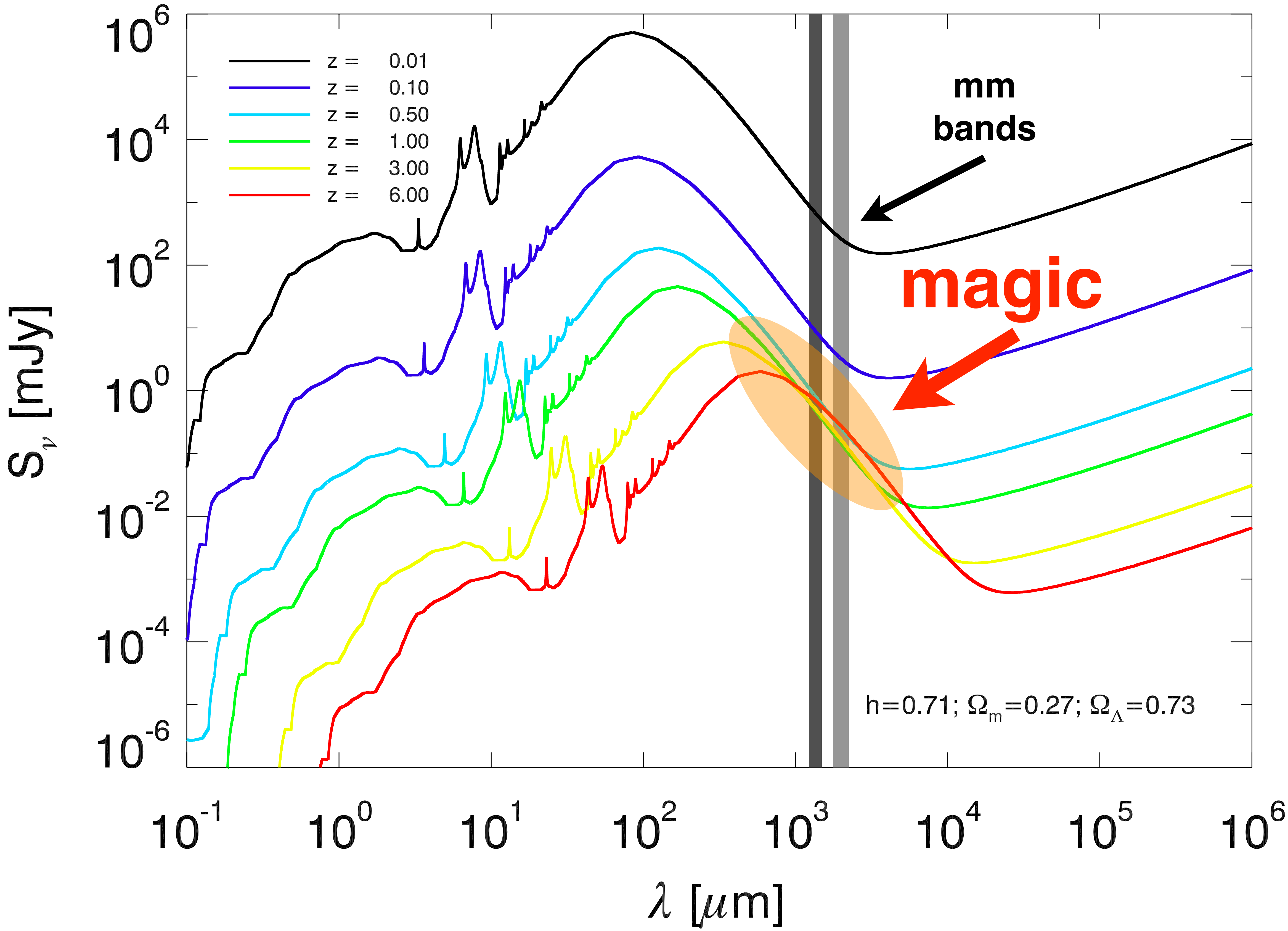




Lagache+ 2005



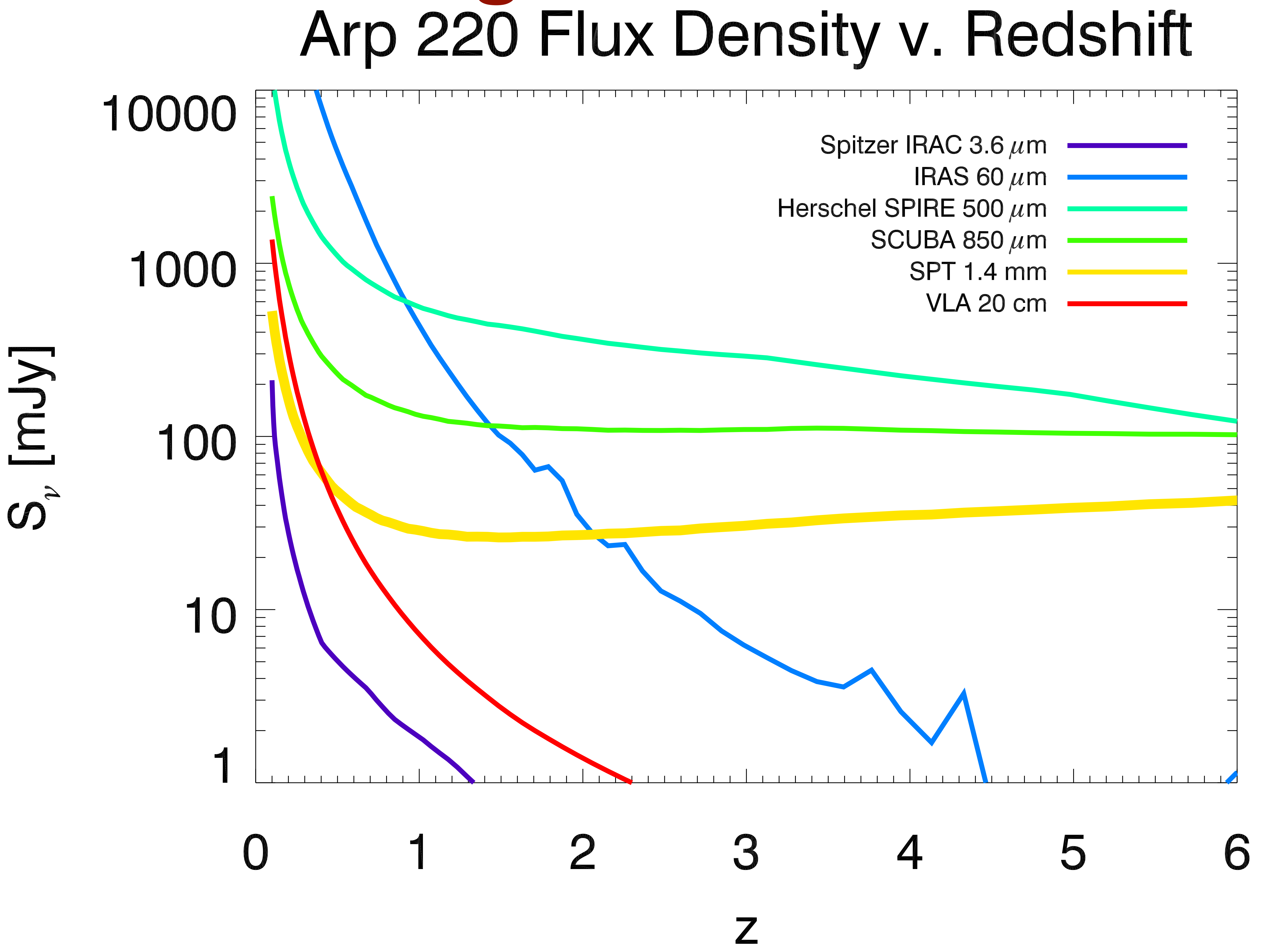
PAH lines
R-J side of modified BB emission from dust
Stellar BB emission
Balmer break
Lyman break
Synchrotron emission
z = 0.01
z = 0.10
z = 0.50
z = 1.00
z = 3.00
z = 6.00
Inaccessible from the ground
h=0.71; Ωm=0.27; ΩΛ=0.73
Sν [mJy]
λ [μm]

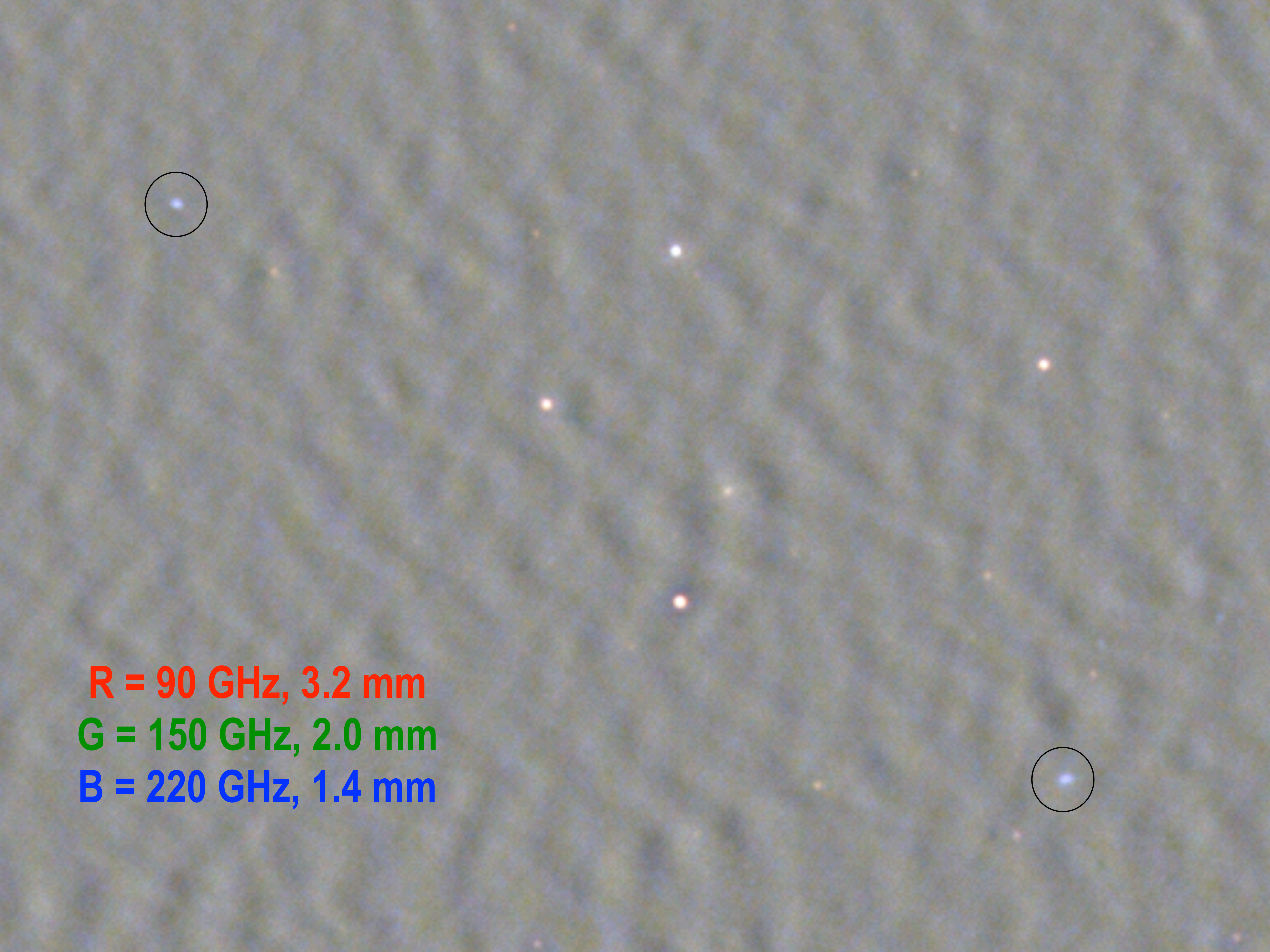


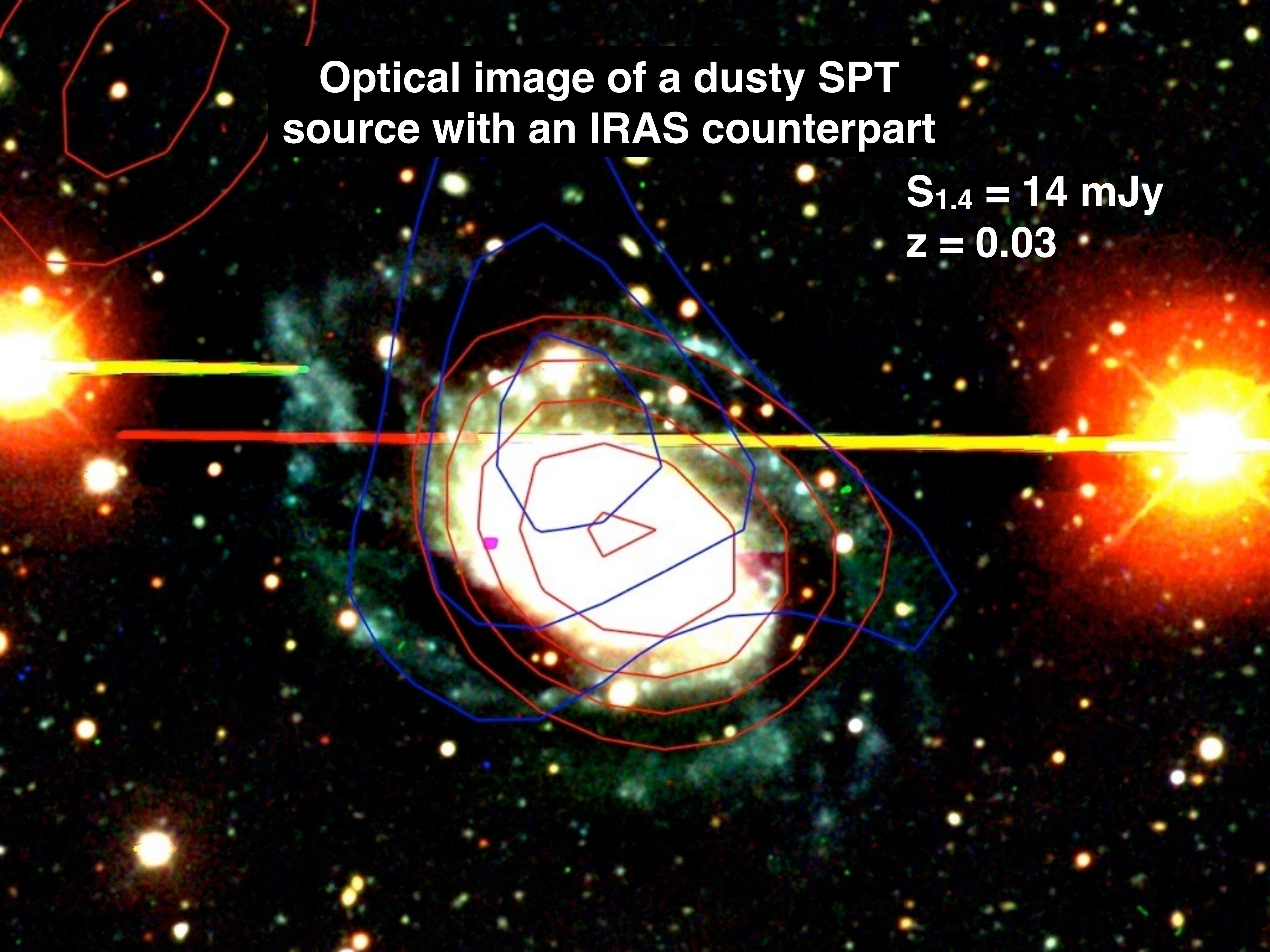
z = 0.01
z = 0.10
z = 0.50
z = 1.00
z = 3.00
z = 6.00
mm bands
magic
h=0.71; Ω_m=0.27; Ω_Λ=0.73
S_ν [mJy]
λ [μm]
10^{6}
10^{4}
10^{2}
10^{0}
10^{-2}
10^{-4}
10^{-6}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}

Sub-mm magic

See Franceschini *et al.* 1991 and Blain & Longair 1993

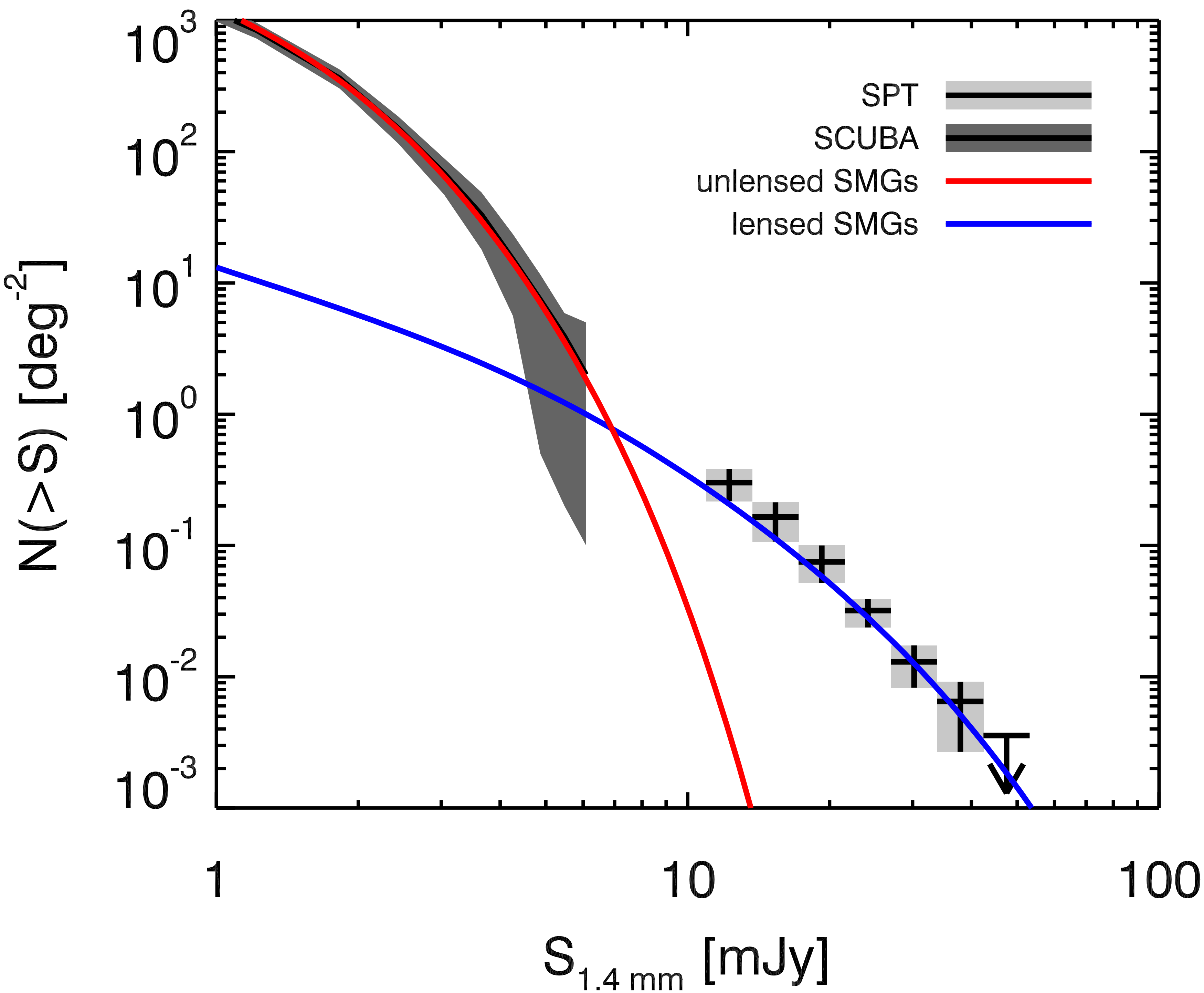



R = 90 GHz, 3.2 mm
G = 150 GHz, 2.0 mm
B = 220 GHz, 1.4 mm


Optical image of a dusty SPT source with an IRAS counterpart
S1.4 = 14 mJy
z = 0.03

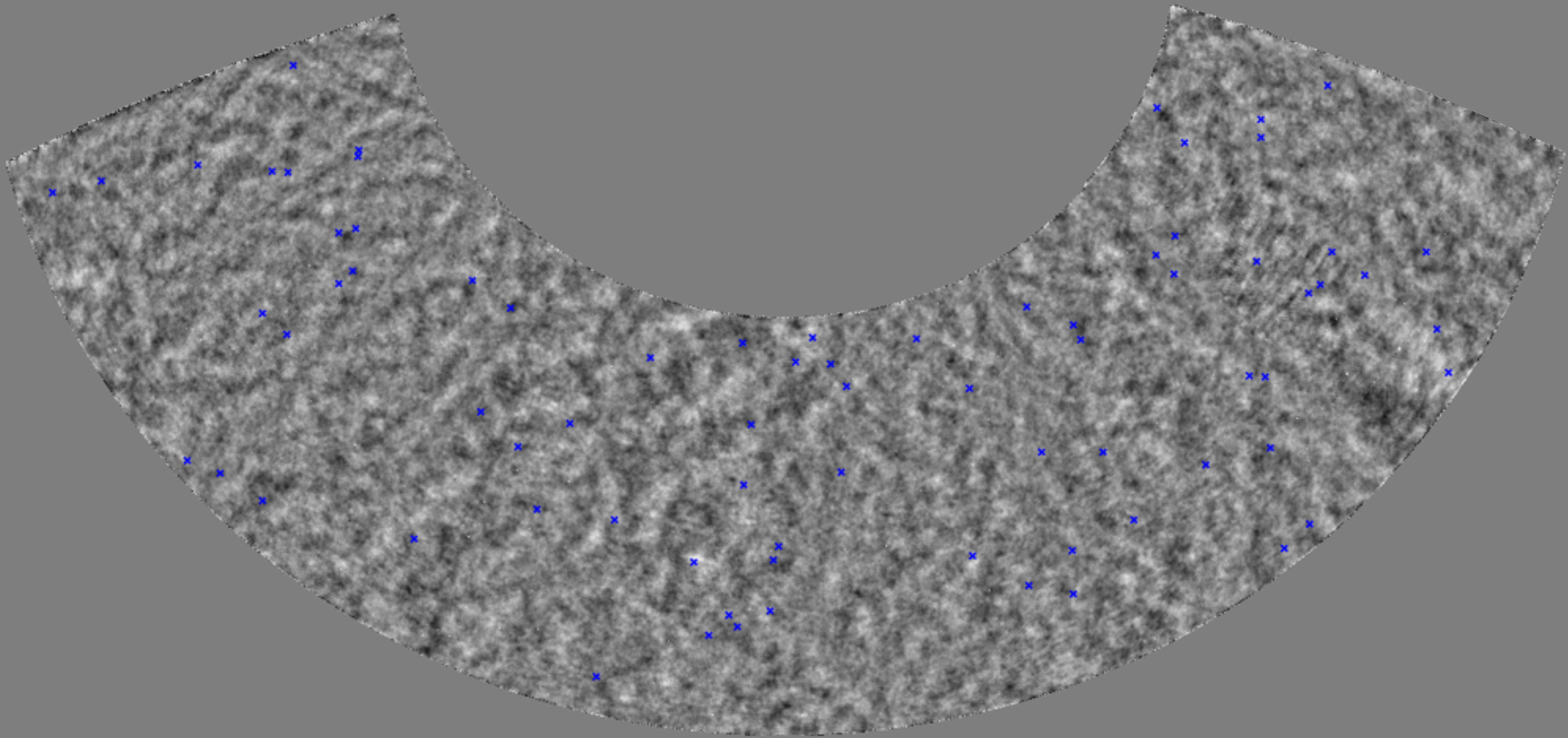
Optical image of a dusty SPT source without any counterpart

Number counts of submm galaxies on the sky



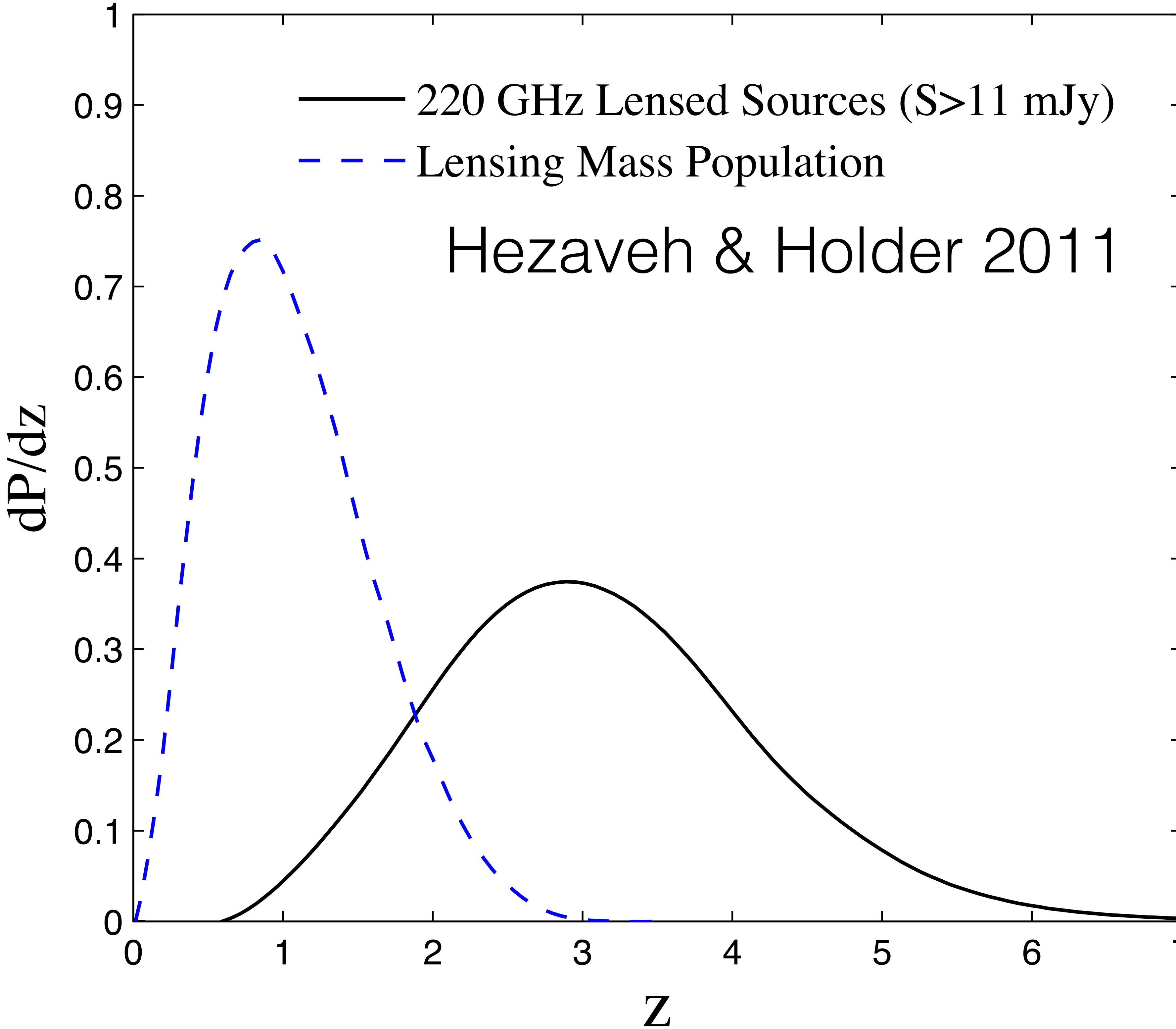
2500 deg^2 SPT survey

76 strongly lensed SMGs at $S_{1.4mm} > 20$ mJy



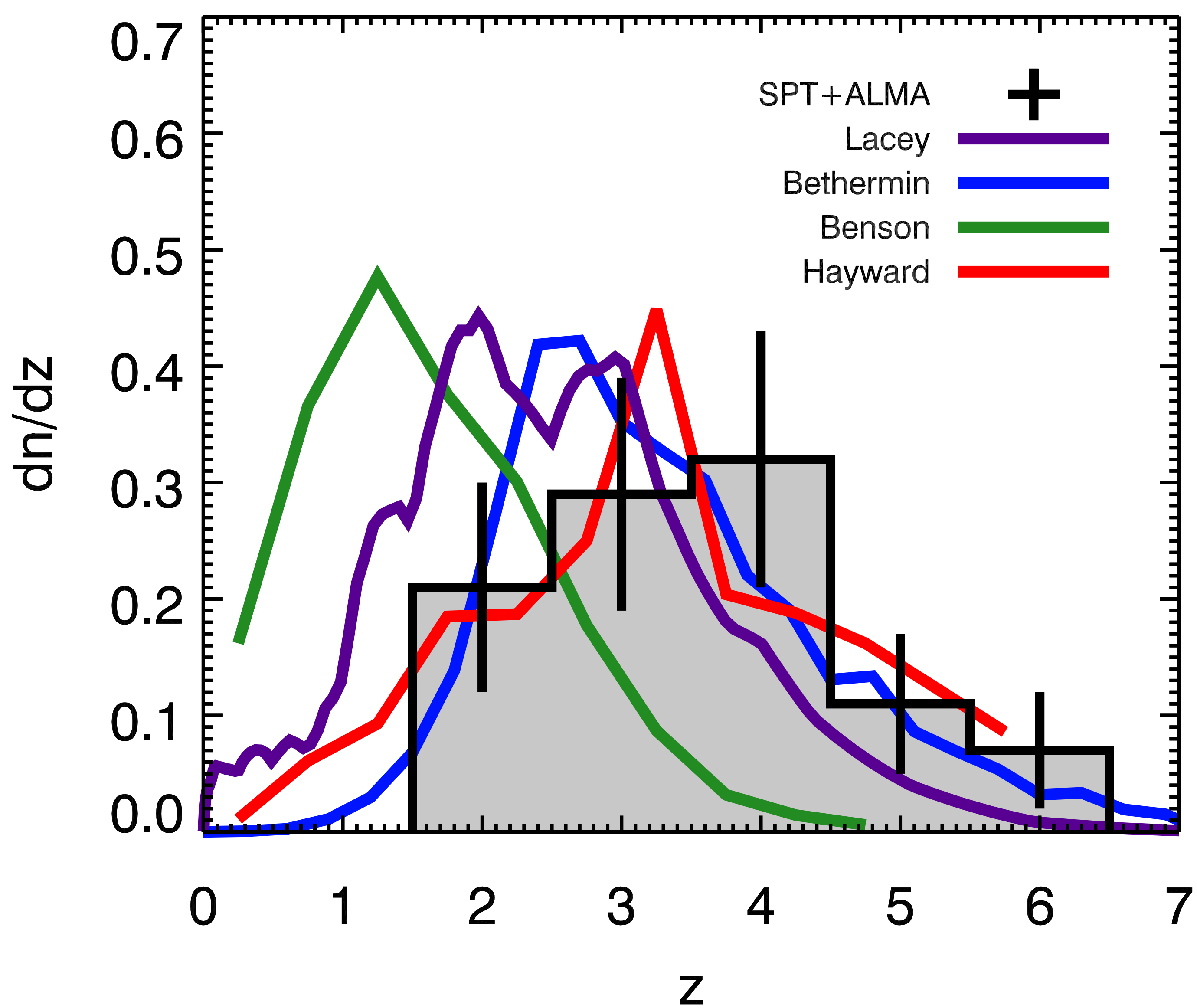
~100 sources total

theoretical n(z) of foreground lenses and background sources



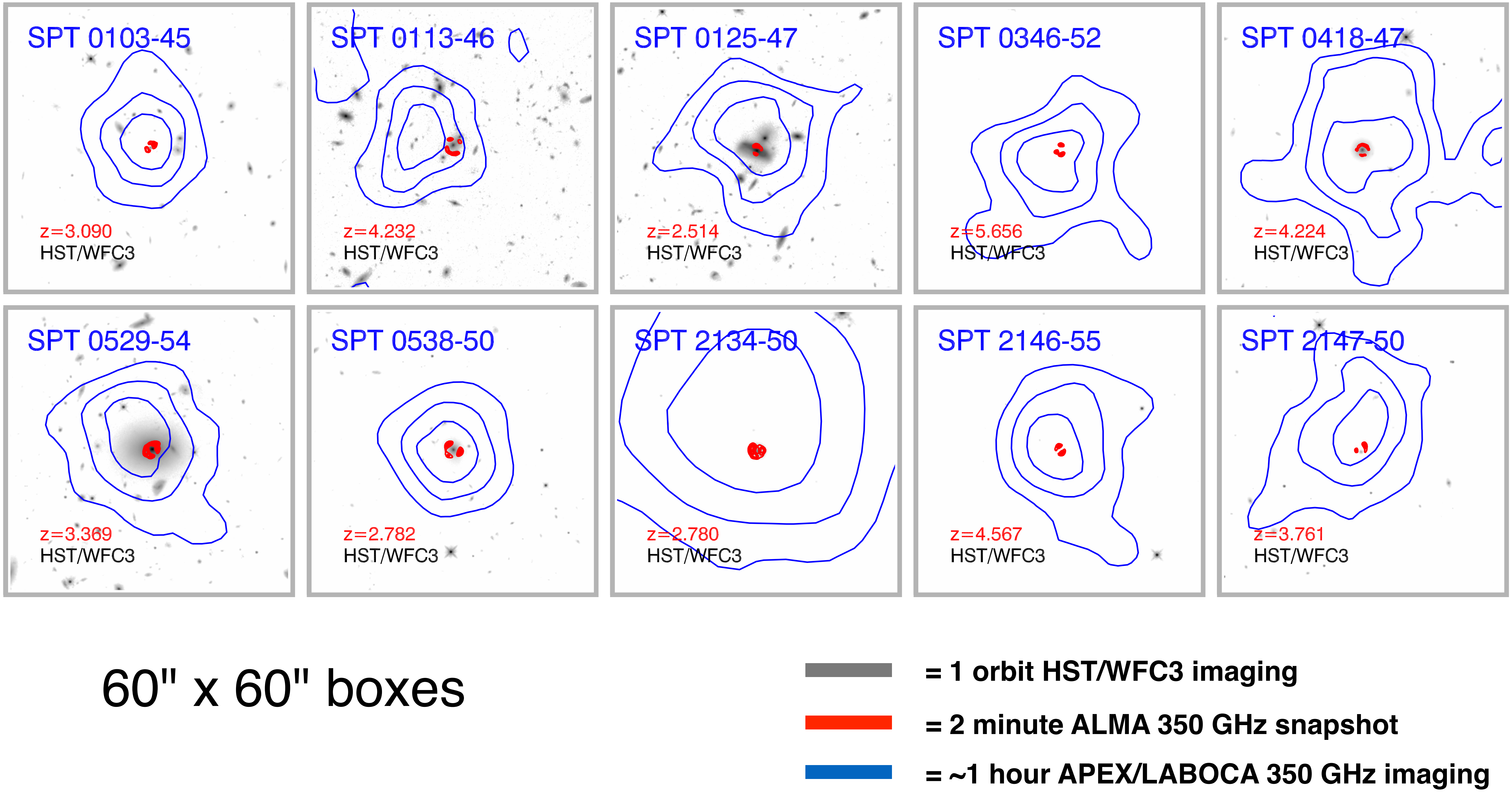
SPT+ALMA redshift distribution

Weiss *et al.* 2013 ApJ



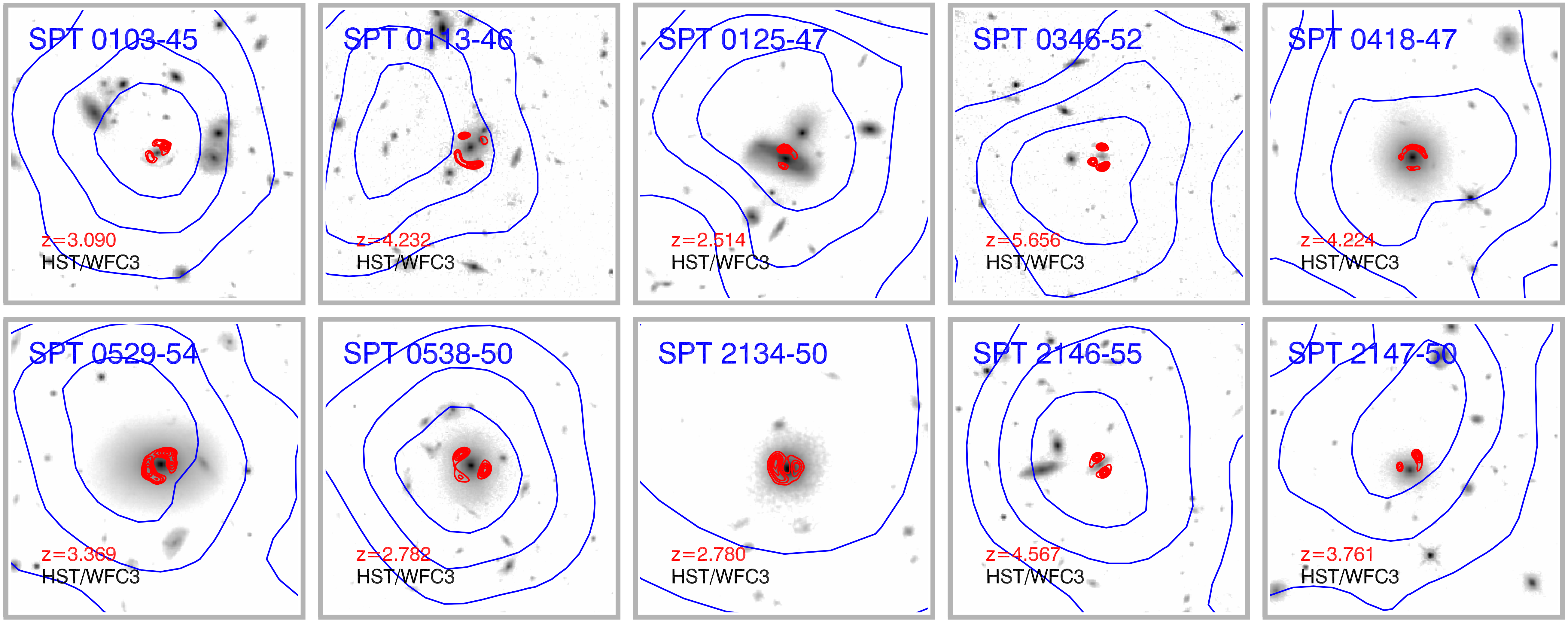
- well-defined selection function based off of a uniform flux cut
- obtained redshifts for 90% of sources without any additional selection biases
- <z>=3.5
- measured redshift distribution already provides powerful constraints for models of galaxy evolution

ALMA Cycle 0 Band 7 350 GHz
2 minute snapshots with 16 antennas



60" x 60" boxes

ALMA Cycle 0 Band 7 350 GHz
2 minute snapshots with 16 antennas



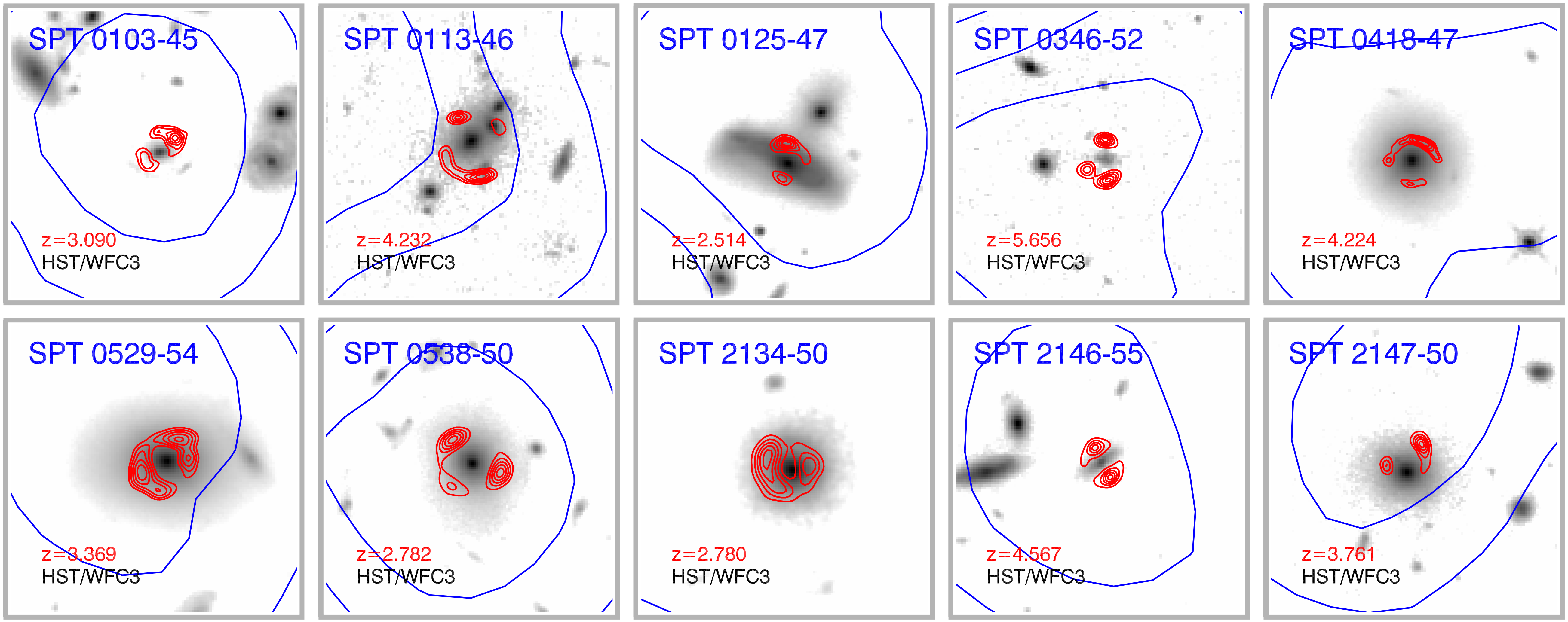
30" x 30" boxes

= 1 orbit HST/WFC3 imaging

= 2 minute ALMA 350 GHz snapshot

= ~1 hour APEX/LABOCA 350 GHz imaging

ALMA Cycle 0 Band 7 350 GHz
2 minute snapshots with 16 antennas



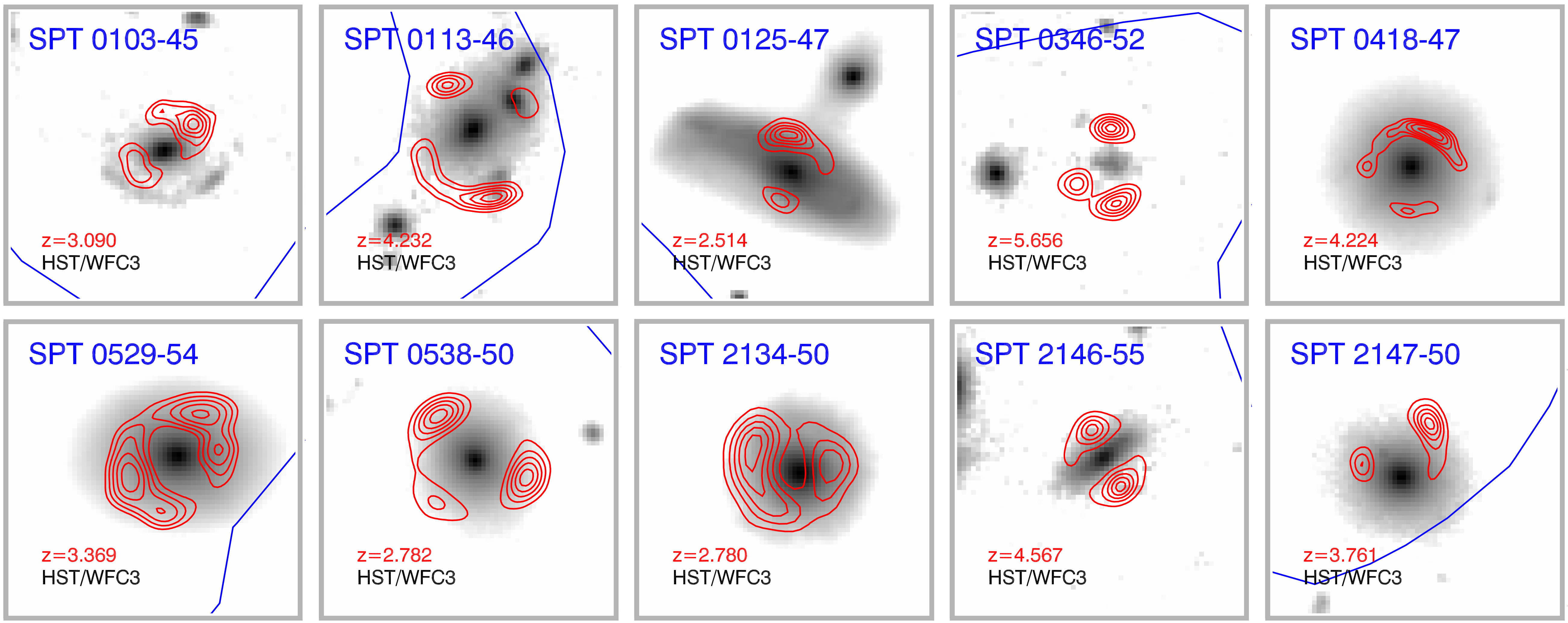
15" x 15" boxes

= 1 orbit HST/WFC3 imaging

= 2 minute ALMA 350 GHz snapshot

= ~1 hour APEX/LABOCA 350 GHz imaging

ALMA Cycle 0 Band 7 350 GHz
2 minute snapshots with 16 antennas



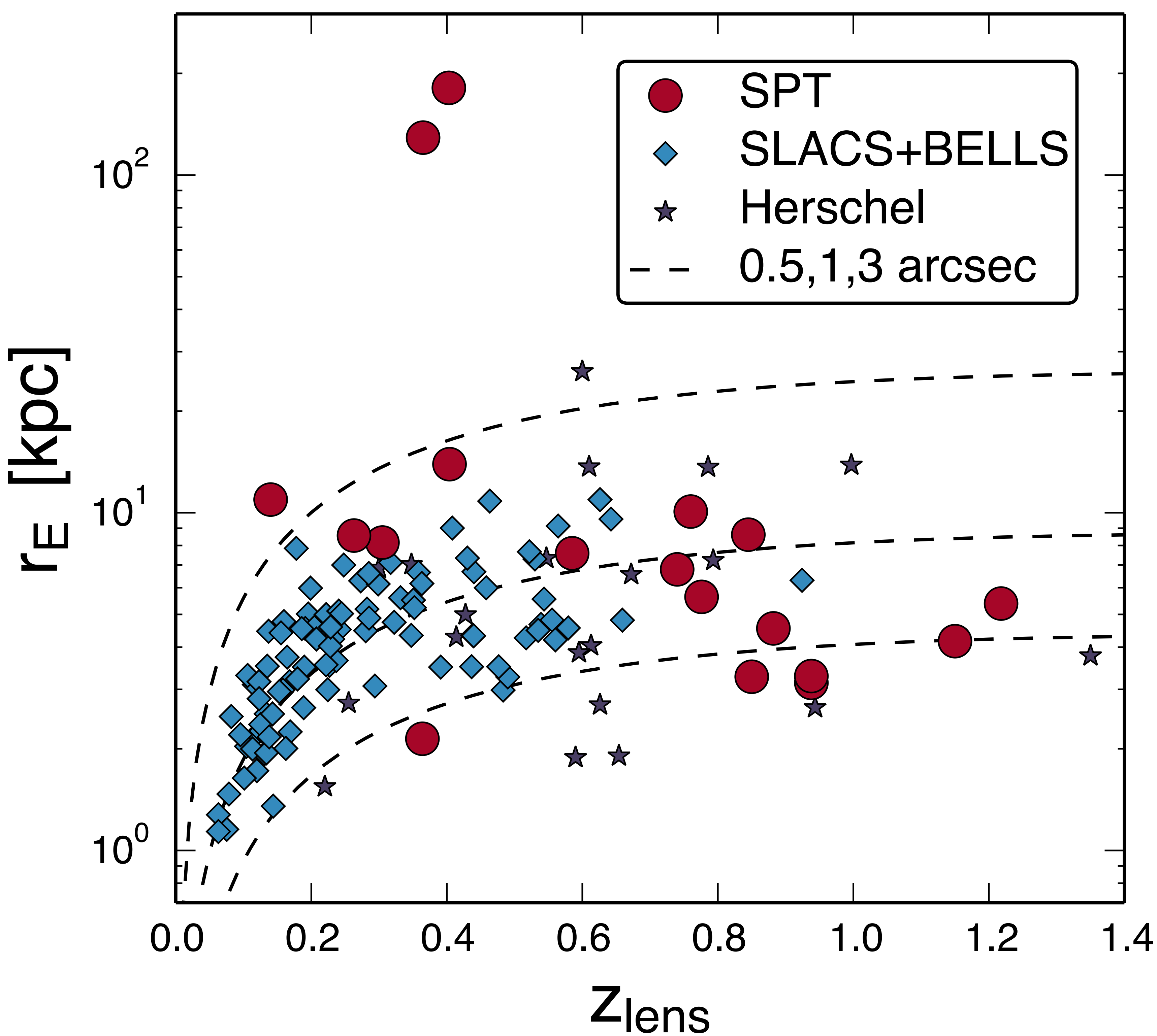
8" x 8" boxes

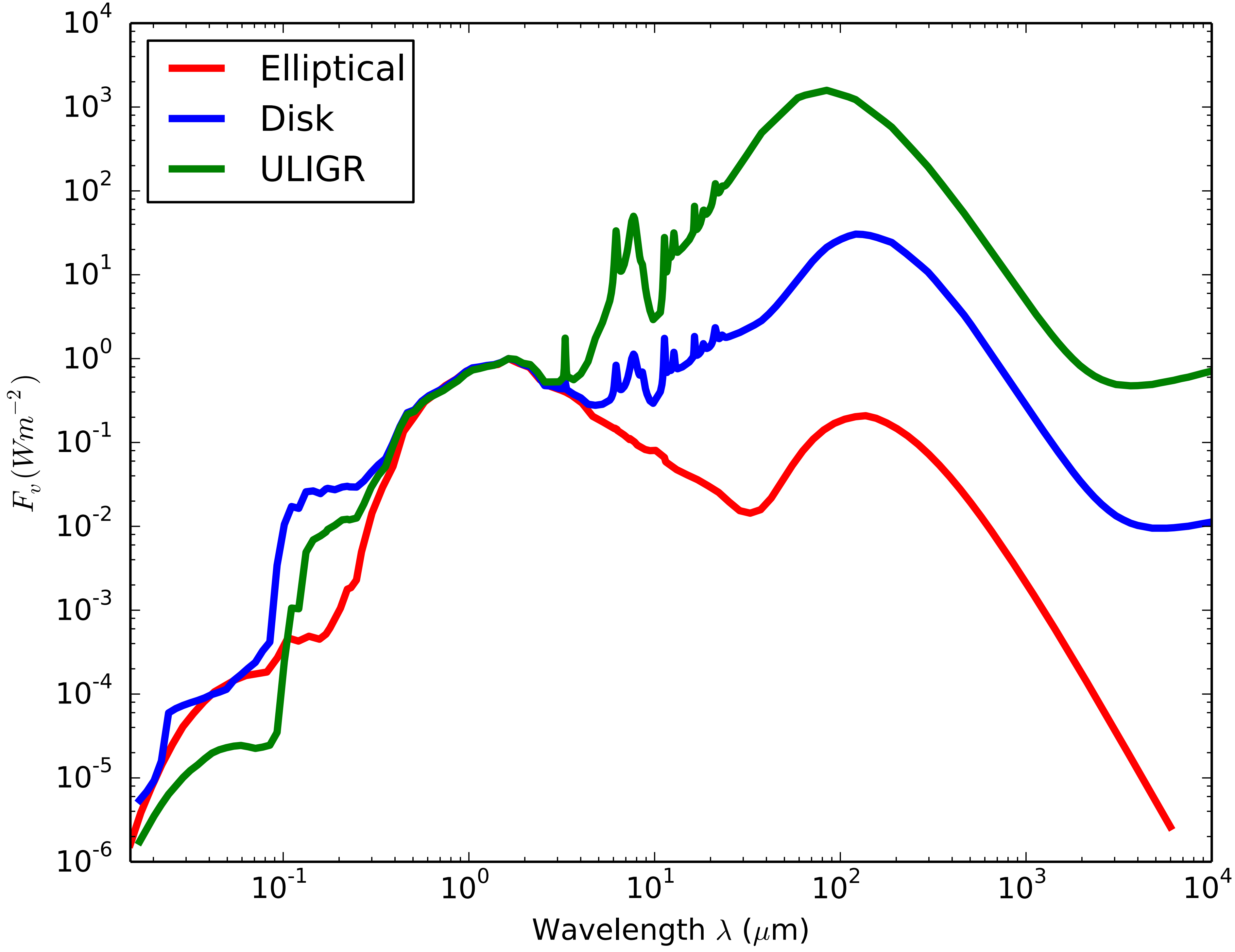
= 1 orbit HST/WFC3 imaging

= 2 minute ALMA 350 GHz snapshot

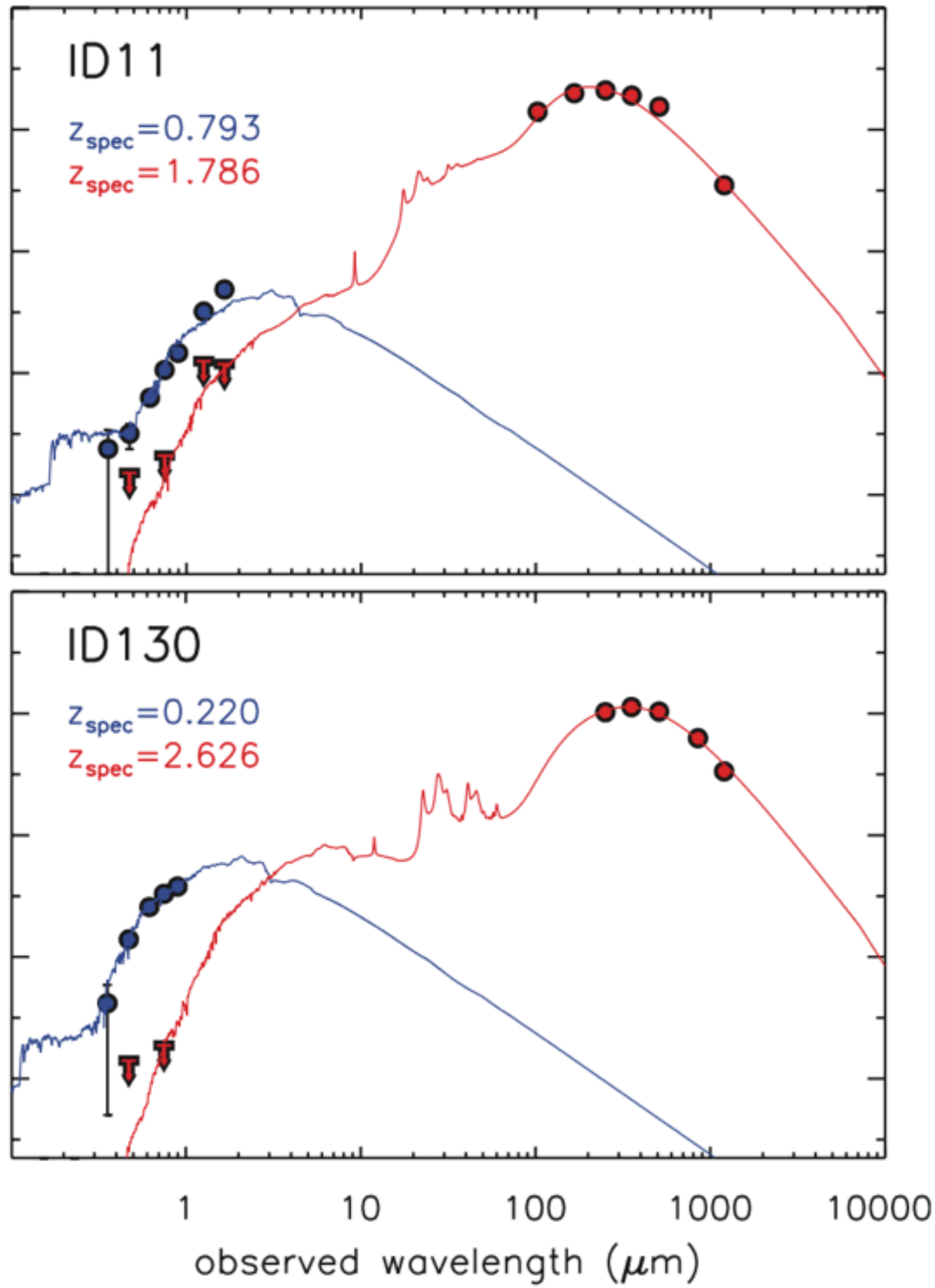
= ~1 hour APEX/LABOCA 350 GHz imaging

empirical Einstein radii of deflectors

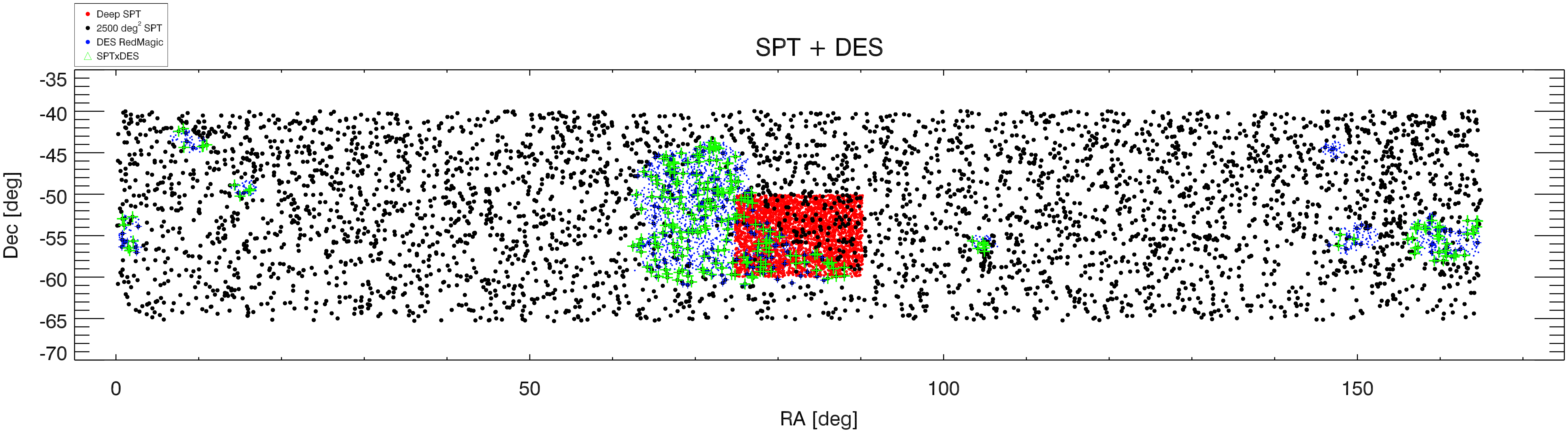




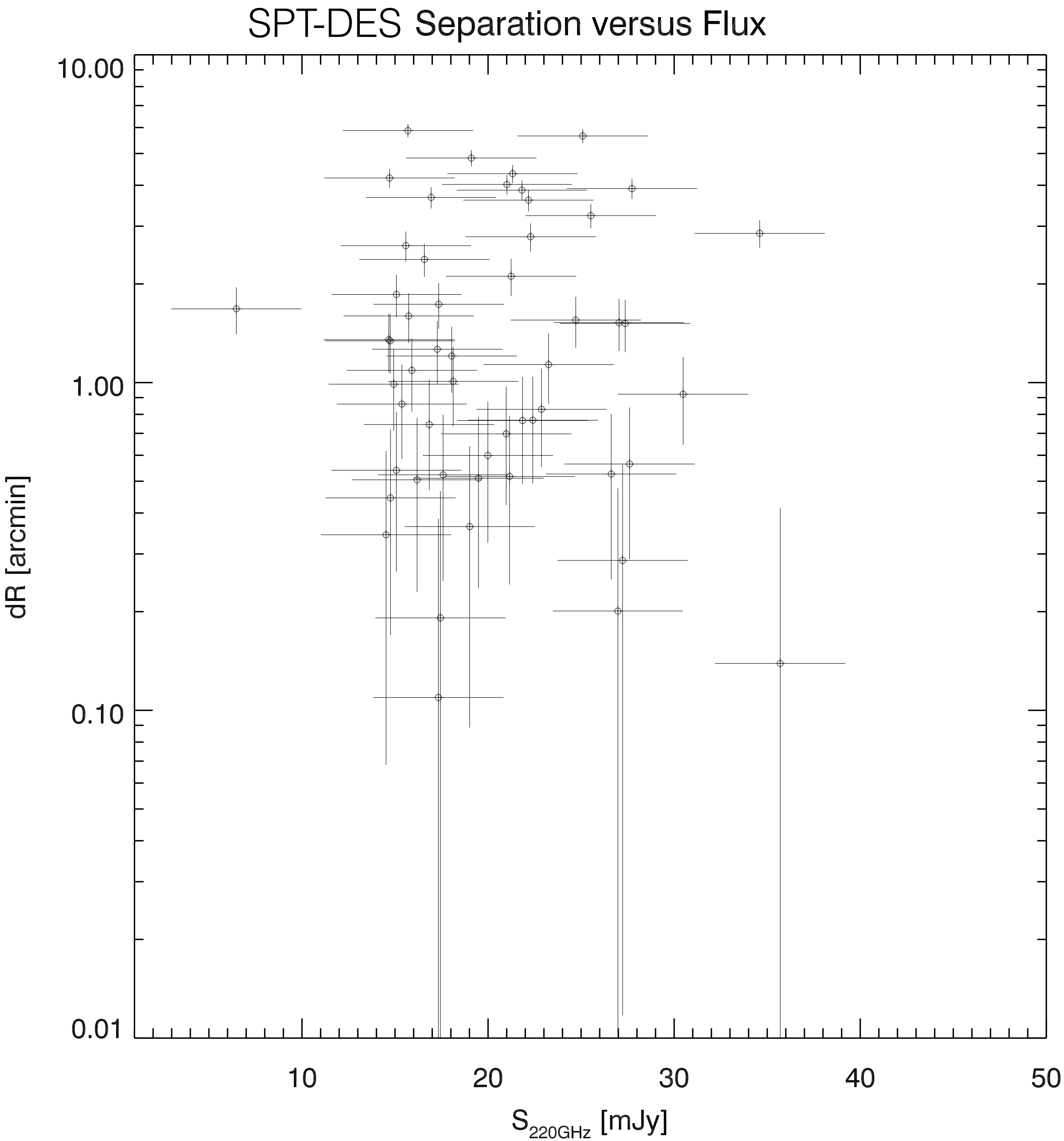
Elliptical
Disk
ULIGR
10^4
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
$F_v (Wm^{-2})$
10^{-1}
10^0
10^1
10^2
10^3
10^4
Wavelength λ (μm)



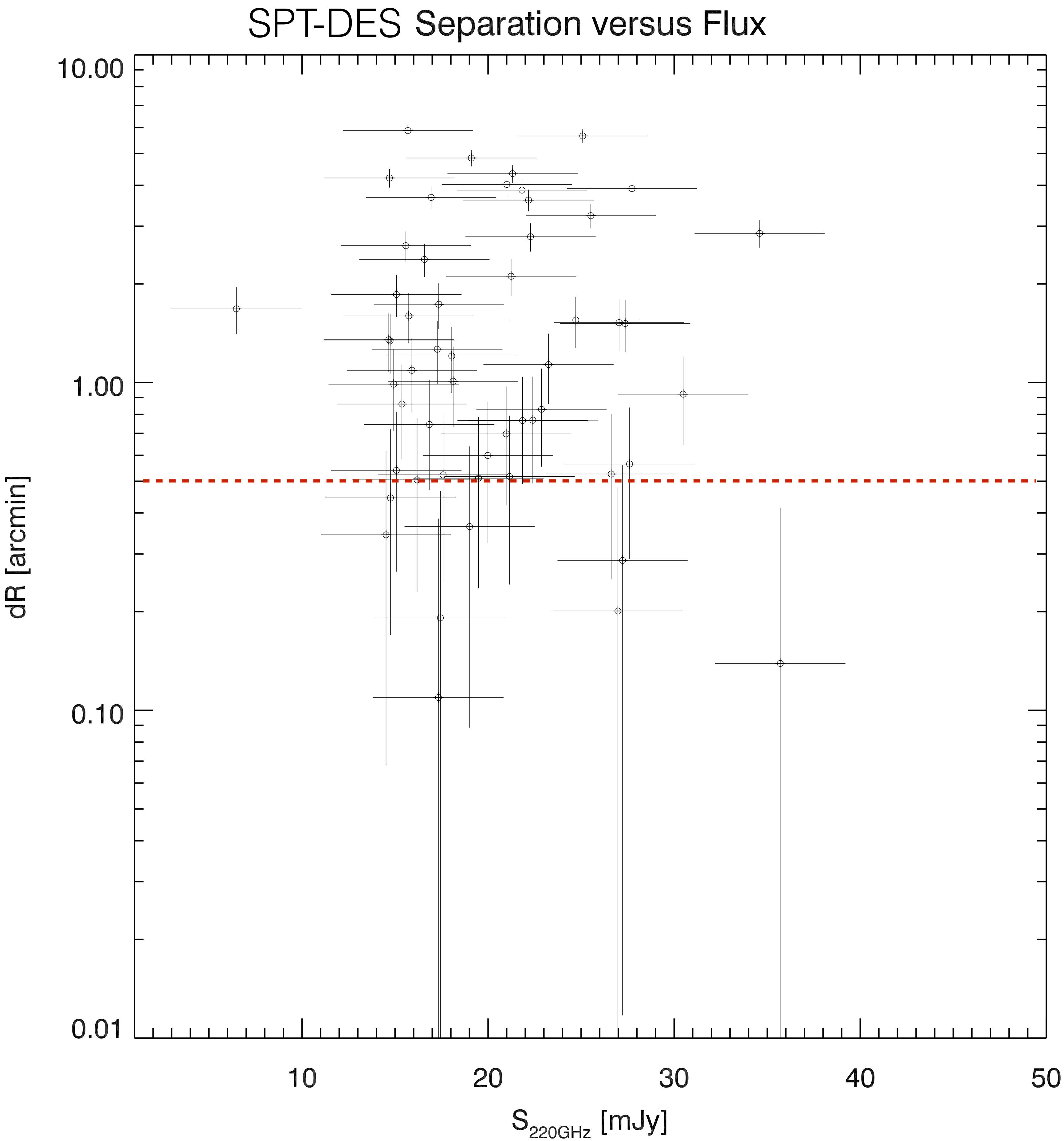
ID11
zspec=0.793
zspec=1.786
ID130
zspec=0.220
zspec=2.626
1
10
100
1000
10000
observed wavelength (μm)

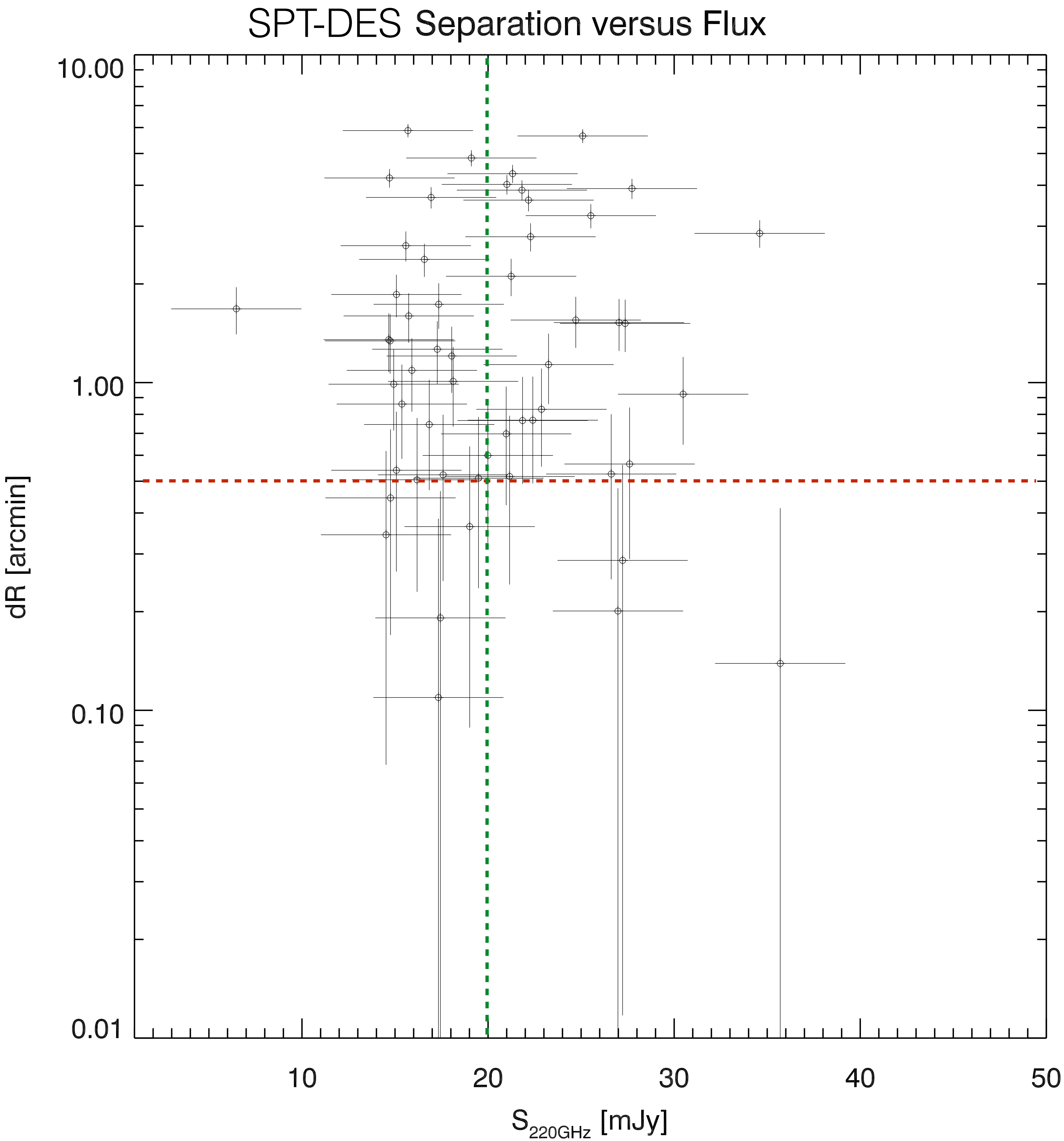


work by Illinois undergraduate Robert Gramillano

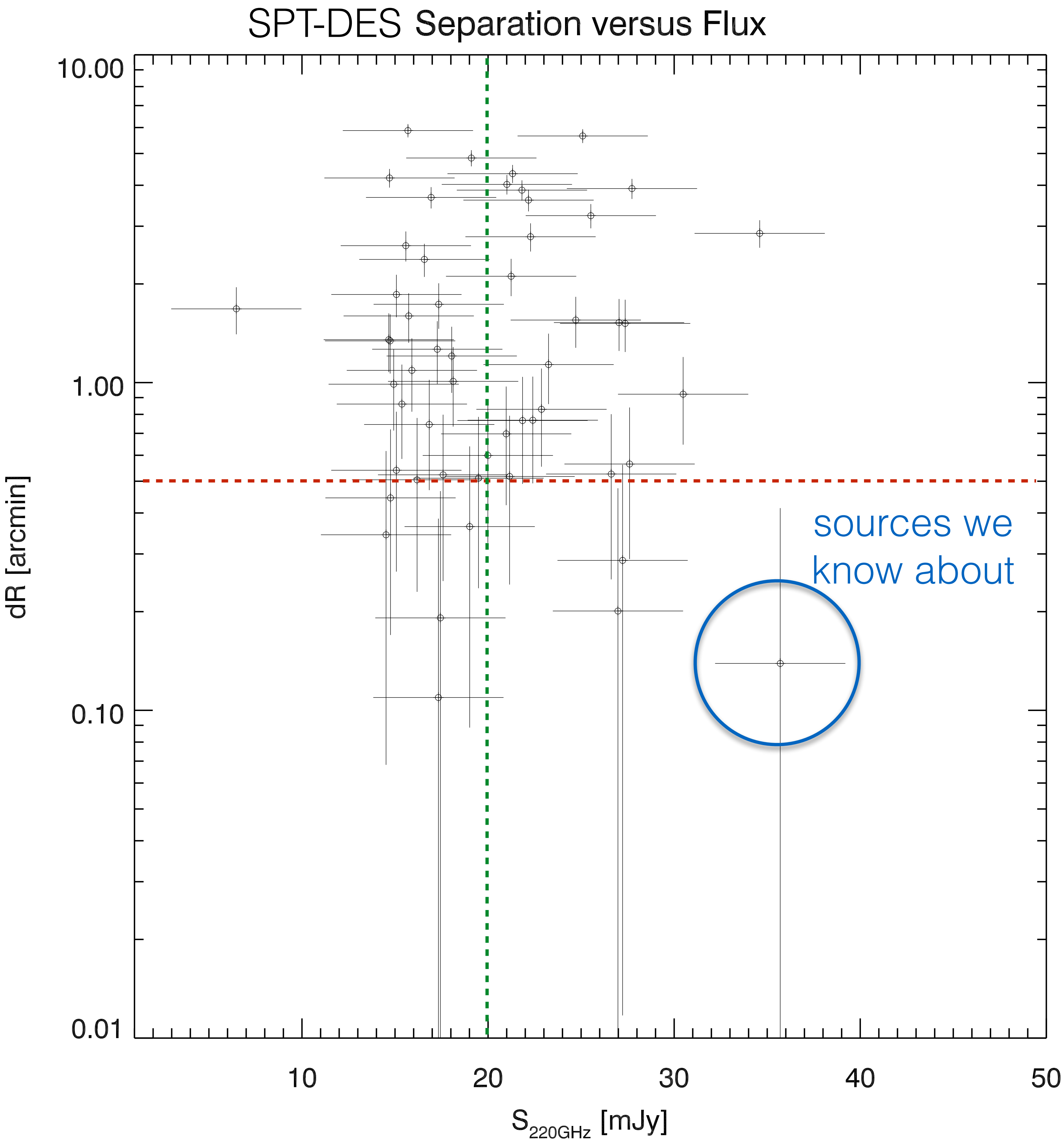


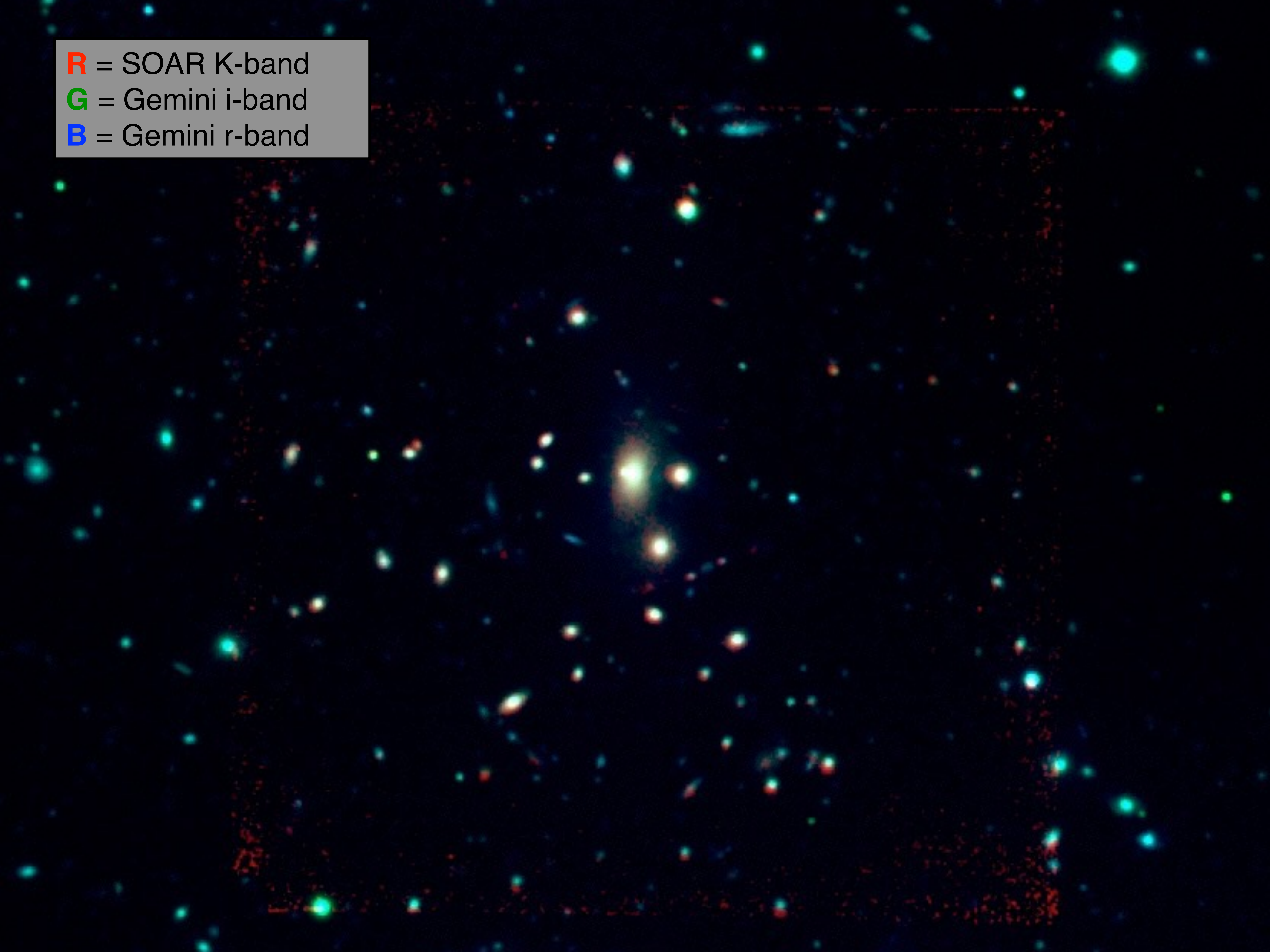
work by Illinois undergraduate Robert Gramillano

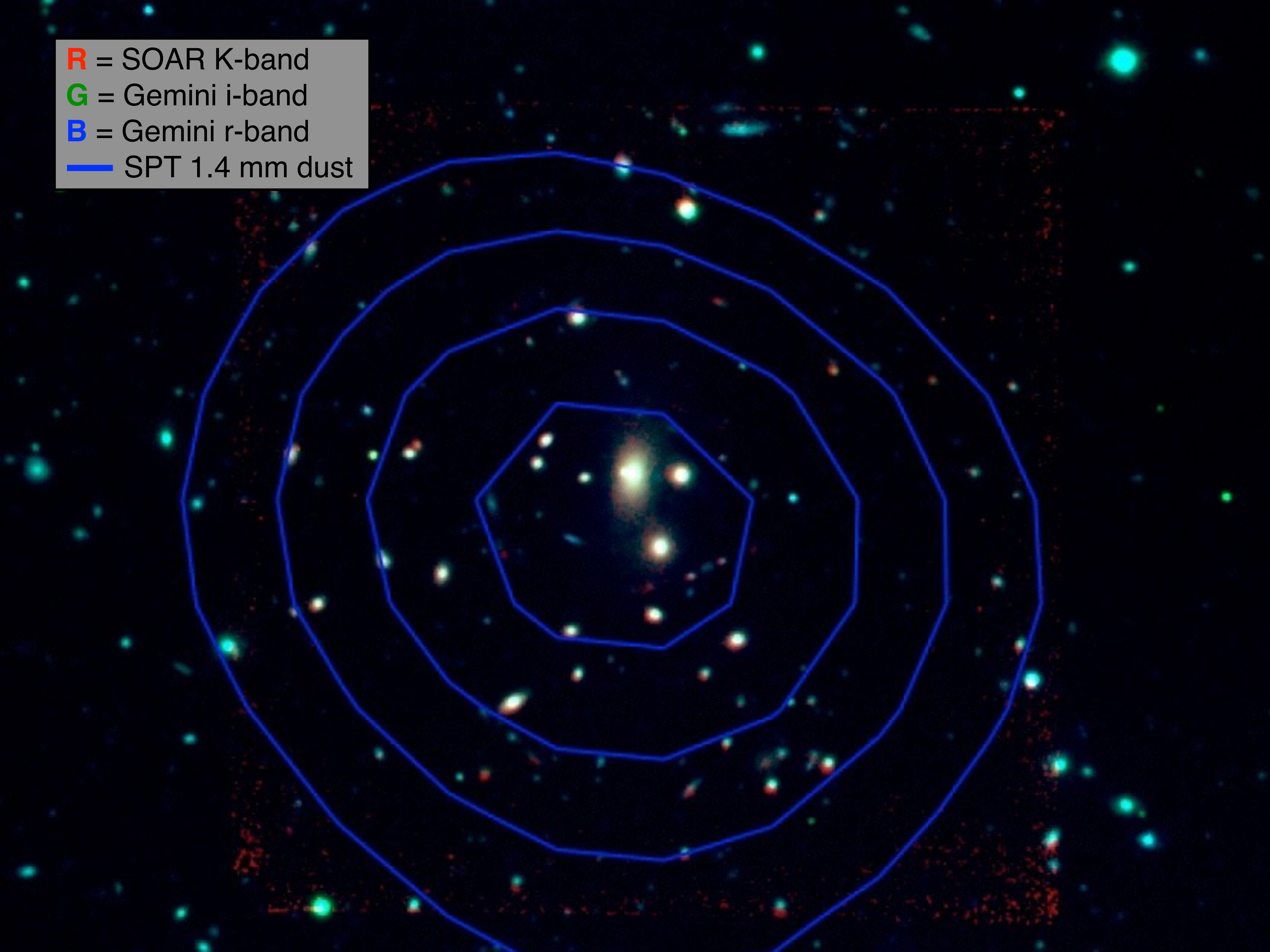

SPT-DES Separation versus Flux
10.00
1.00
0.10
0.01
dR [arcmin]
10
20
30
40
50
S220GHz [mJy]

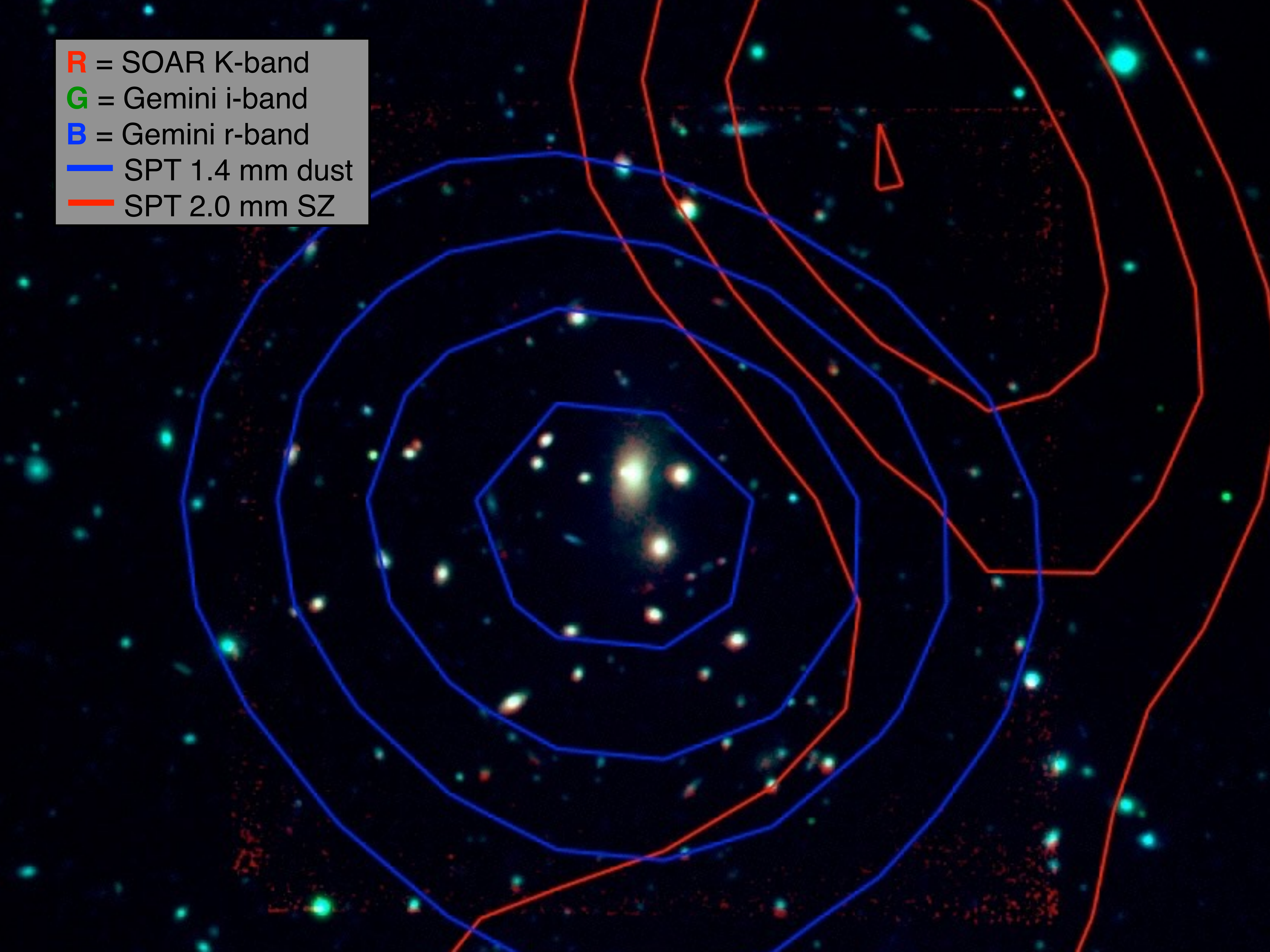


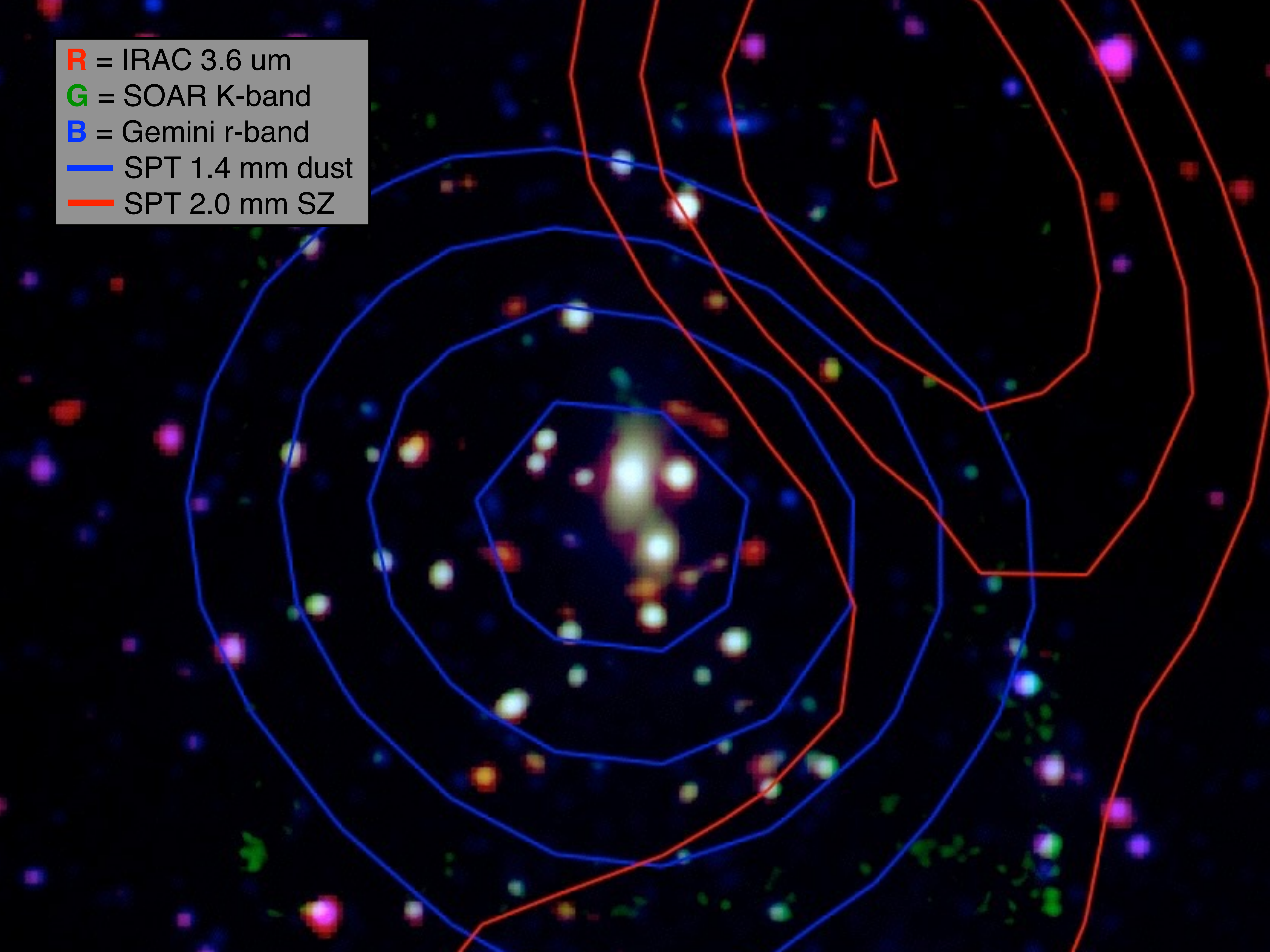
SPT-DES Separation versus Flux
10.00
1.00
0.10
0.01
dR [arcmin]
10
20
30
40
50
S220GHz [mJy]

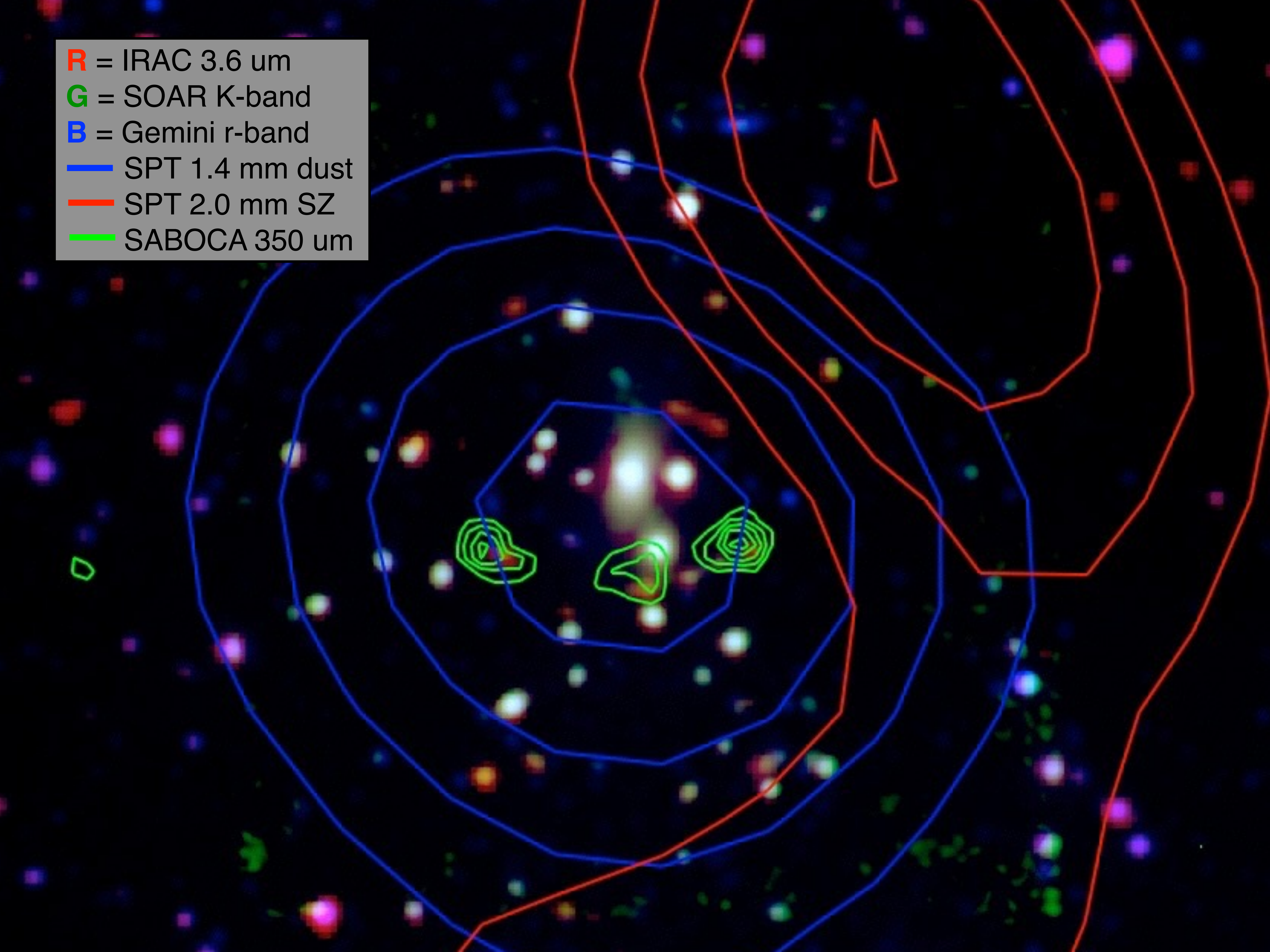

SPT-DES Separation versus Flux
10.00
1.00
0.10
0.01
dR [arcmin]
10
20
30
40
50
S220GHz [mJy]
sources we
know about

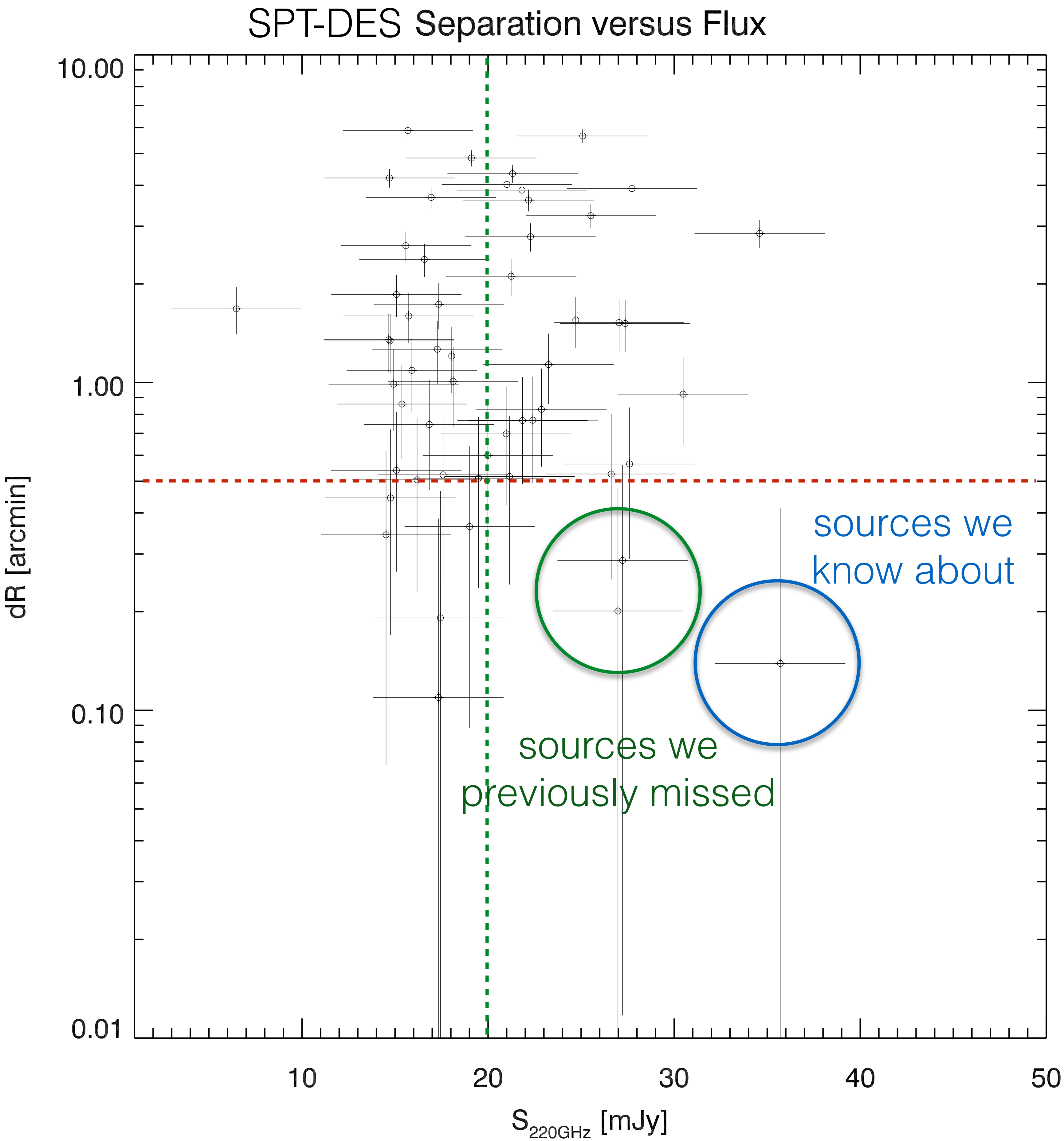

R = SOAR K-band
G = Gemini i-band
B = Gemini r-band


R = SOAR K-band
G = Gemini i-band
B = Gemini r-band
SPT 1.4 mm dust

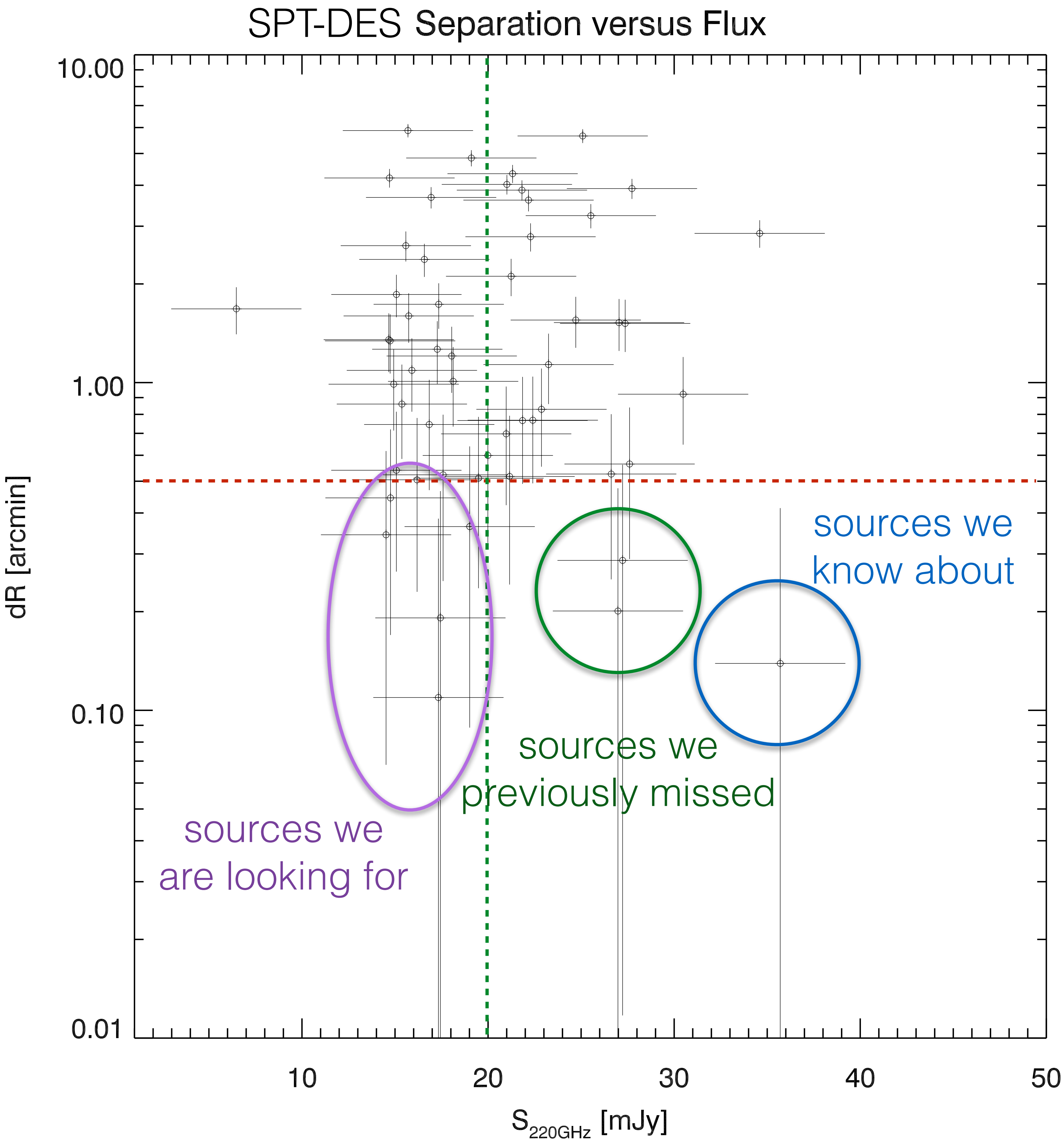

R = SOAR K-band
G = Gemini i-band
B = Gemini r-band
SPT 1.4 mm dust
SPT 2.0 mm SZ


R = IRAC 3.6 um
G = SOAR K-band
B = Gemini r-band
SPT 1.4 mm dust
SPT 2.0 mm SZ


R = IRAC 3.6 um
G = SOAR K-band
B = Gemini r-band
SPT 1.4 mm dust
SPT 2.0 mm SZ
SABOCA 350 um

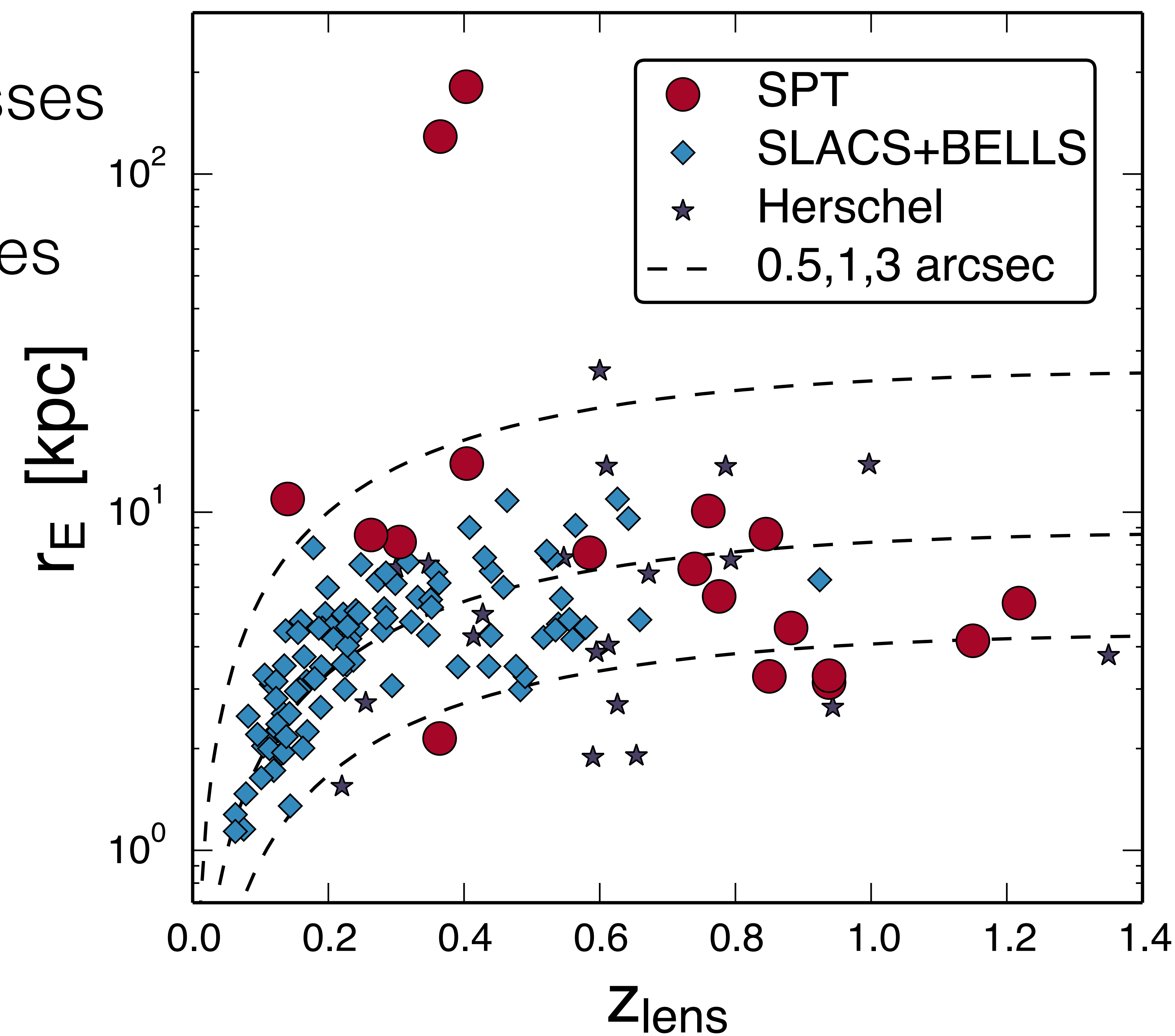


SPT-DES Separation versus Flux
10.00
1.00
0.10
0.01
dR [arcmin]
10
20
30
40
50
S_{220GHz} [mJy]
sources we know about
sources we previously missed


SPT-DES Separation versus Flux
10.00
1.00
0.10
0.01
dR [arcmin]
10
20
30
40
50
S220GHz [mJy]
sources we know about
sources we previously missed
sources we are looking for

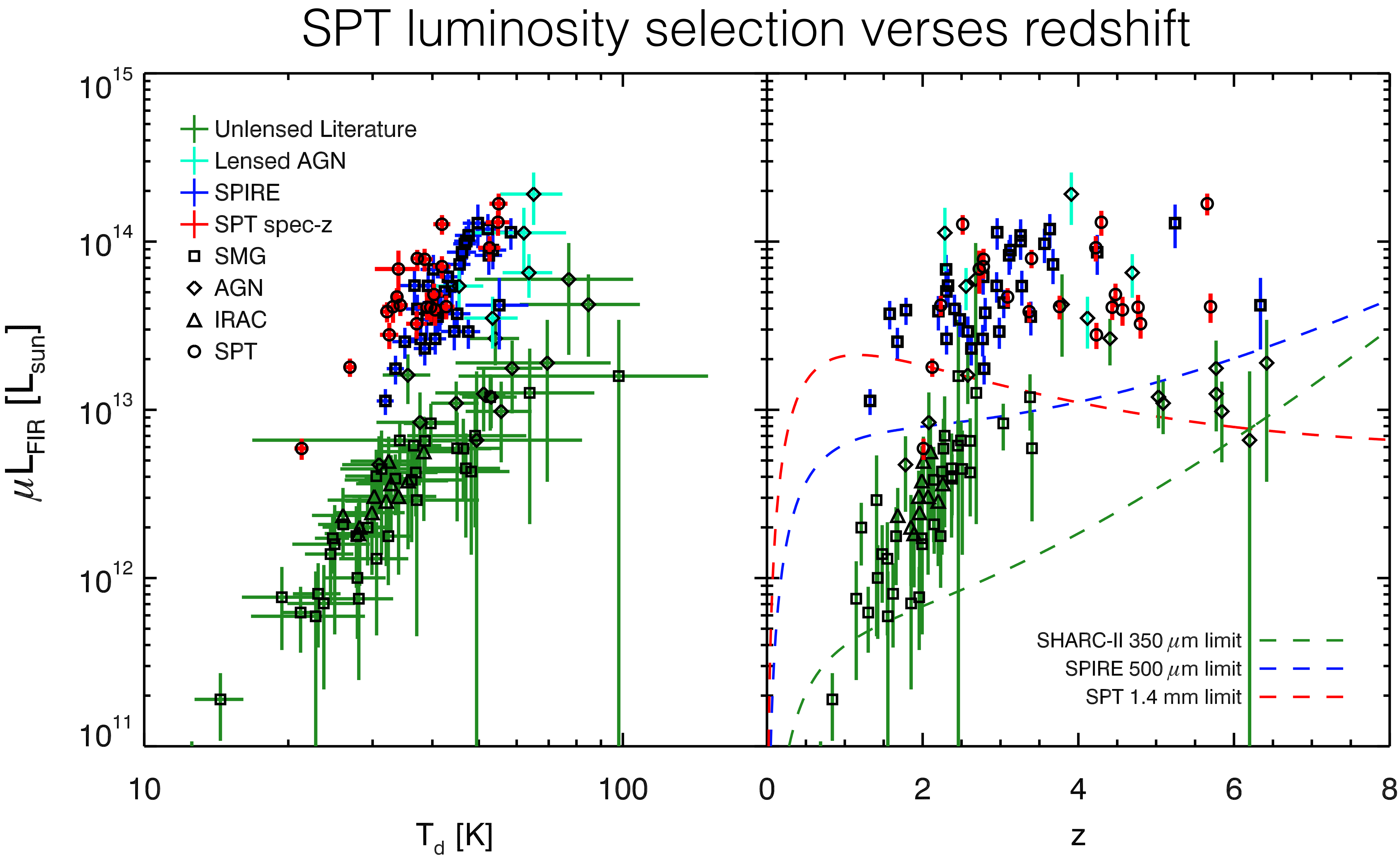
What will DES add ?

measure stellar masses
and M/L ratios
of foreground lenses

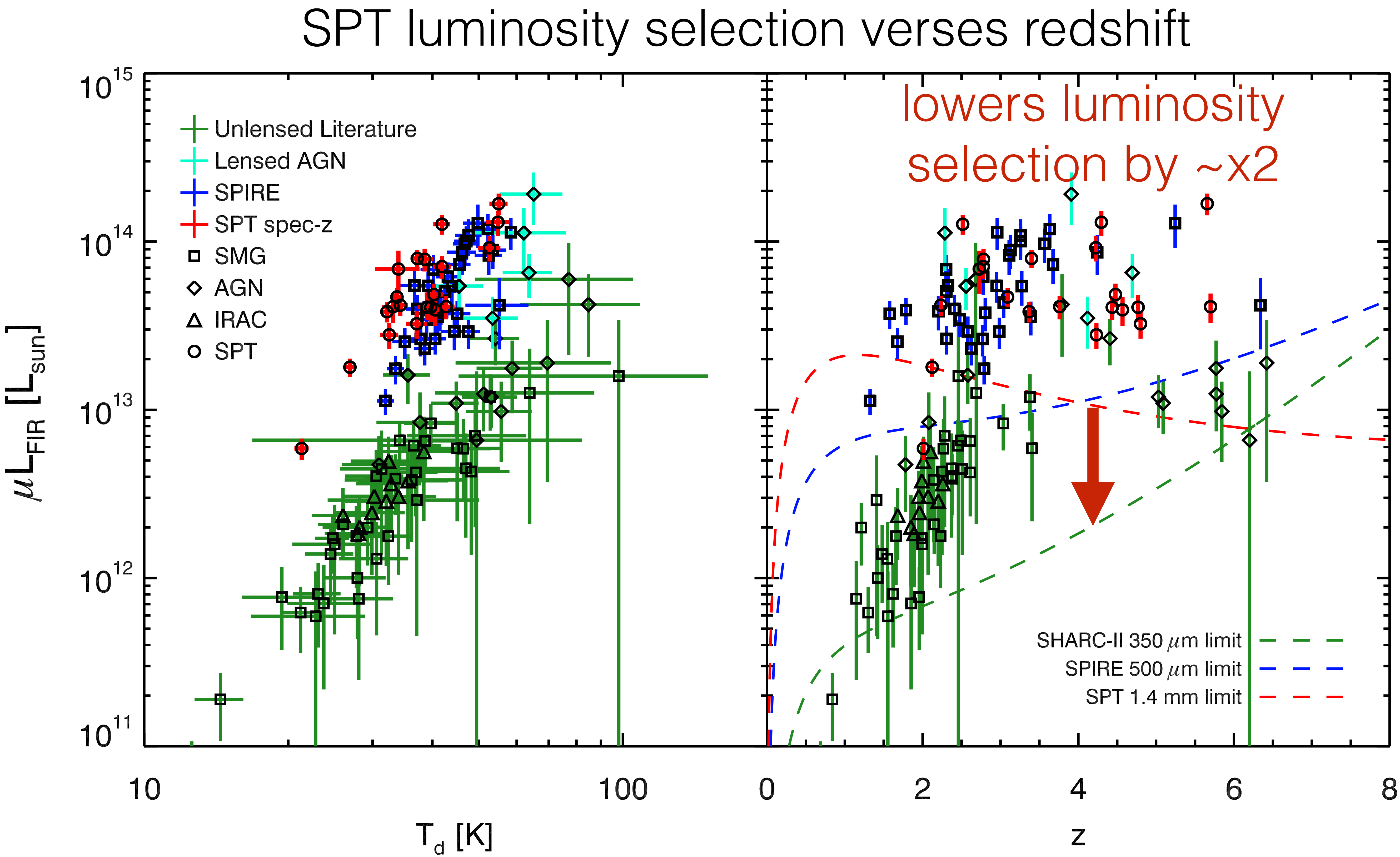


get photometric redshifts for missing sources

What will DES add ?



What will DES add ?



What will DES add ?