The Contribution of Galaxies to the Background at 3 GHz

B

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Atacama Large Millimeter/submillimeter Array
Expanded Very Large Array
Robert C. Byrd Green Bank Telescope
Very Long Baseline Array

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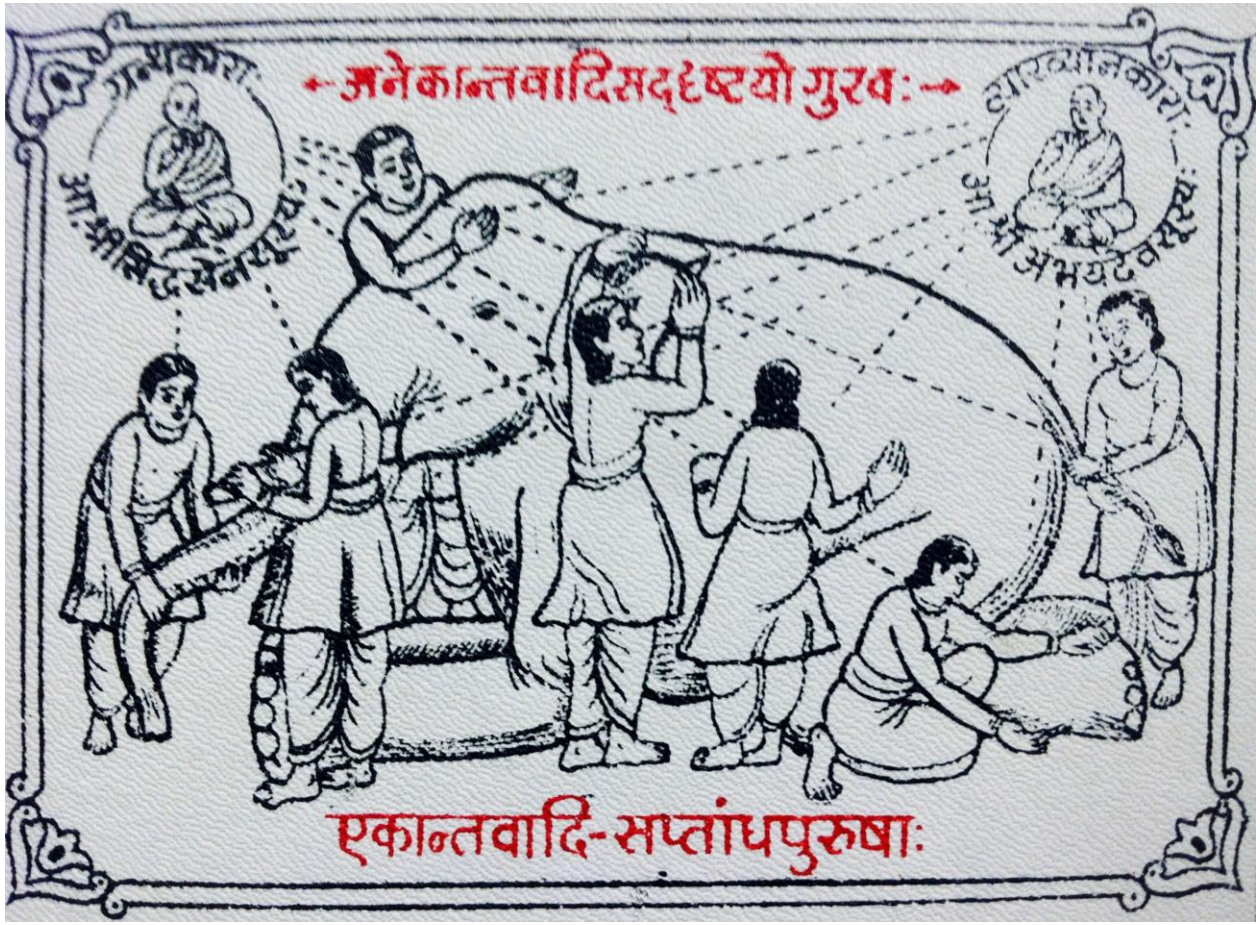
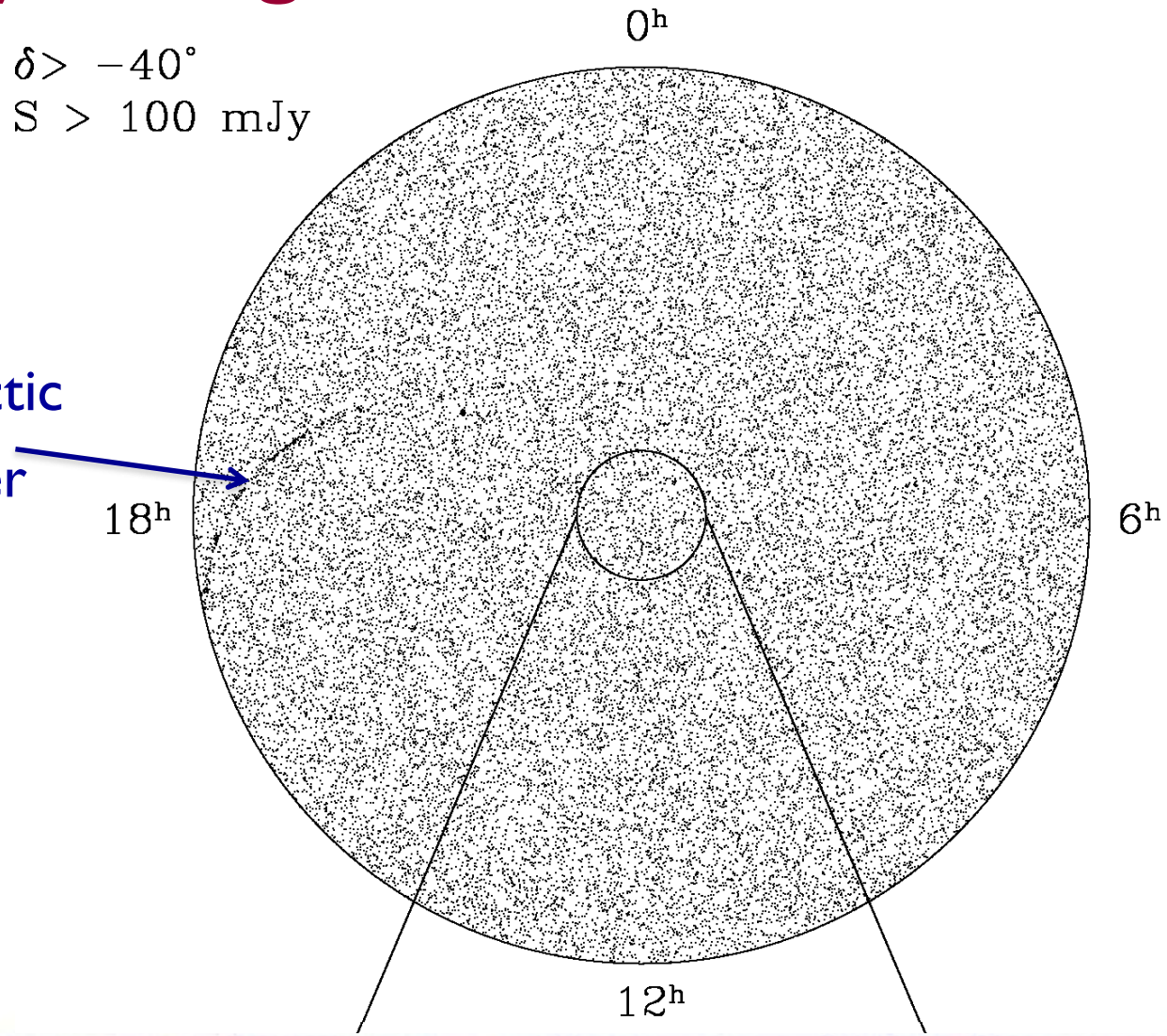
The blind men and the elephant

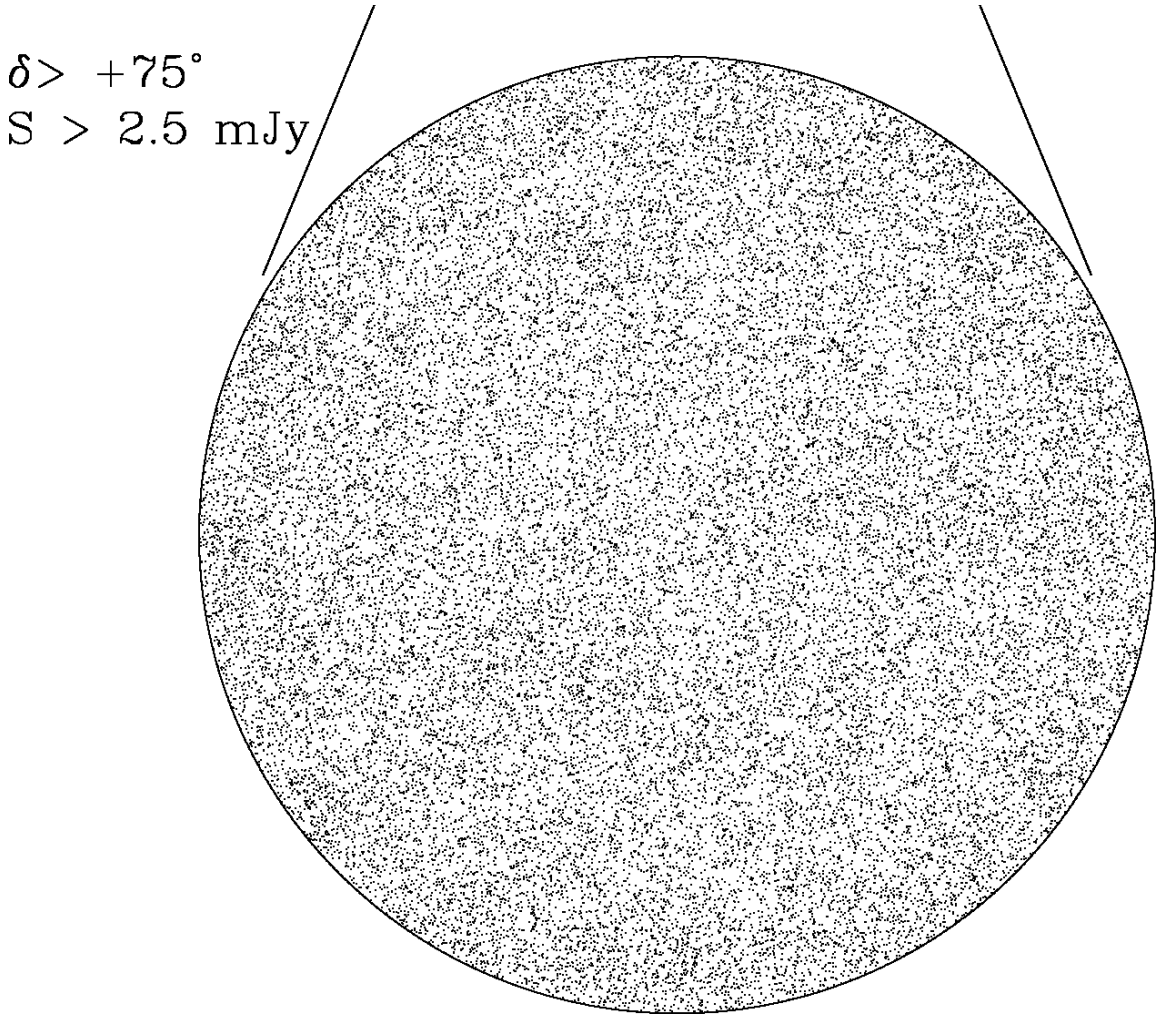


"Due to extreme delusion produced on account of a partial viewpoint, the immature deny one aspect and try to establish another. This is the maxim of the blind (men) and the elephant."

At 45 arcsec resolution, 1.4 GHz sources are mostly extragalactic,



very isotropic, and hence very distant



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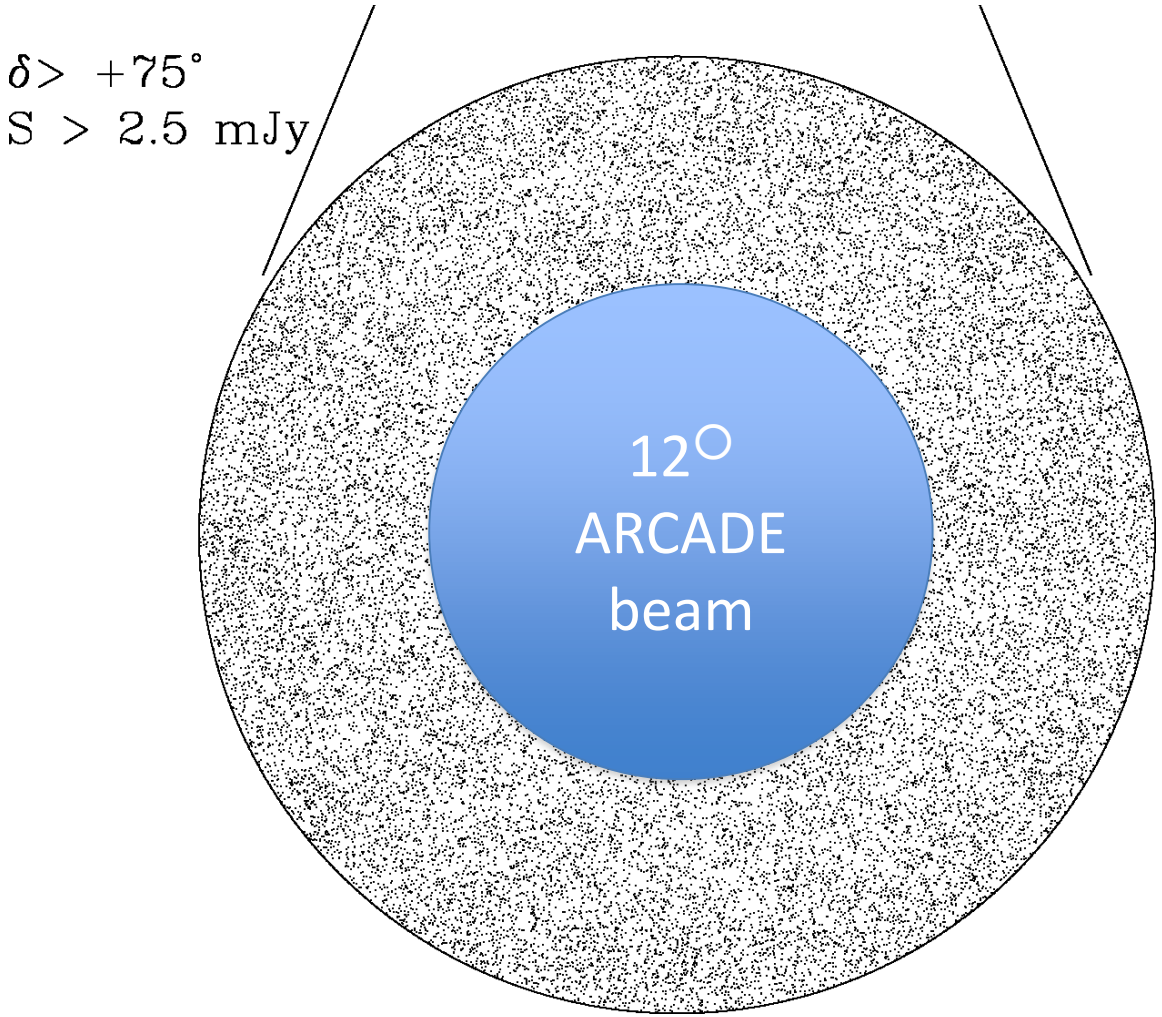
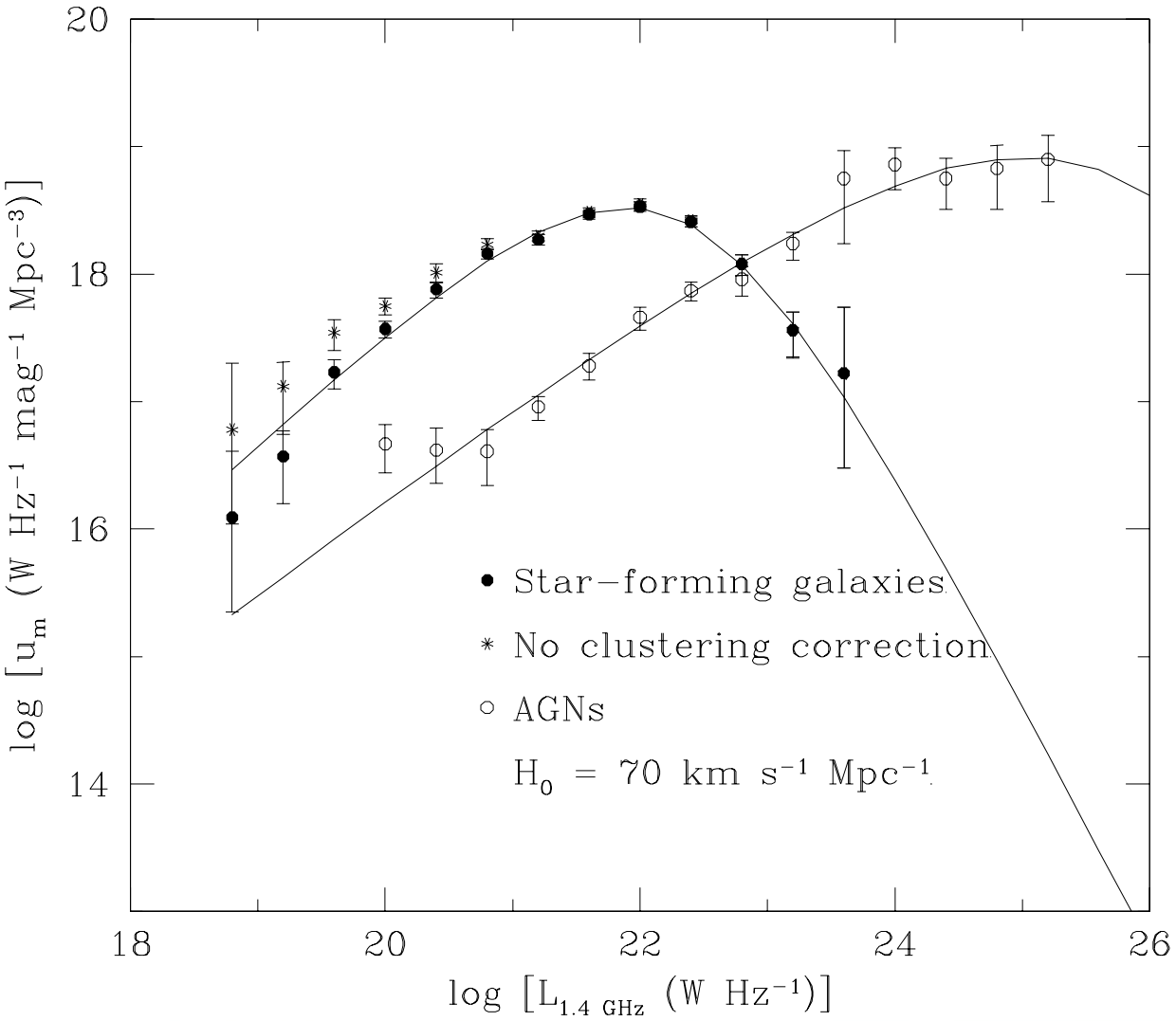
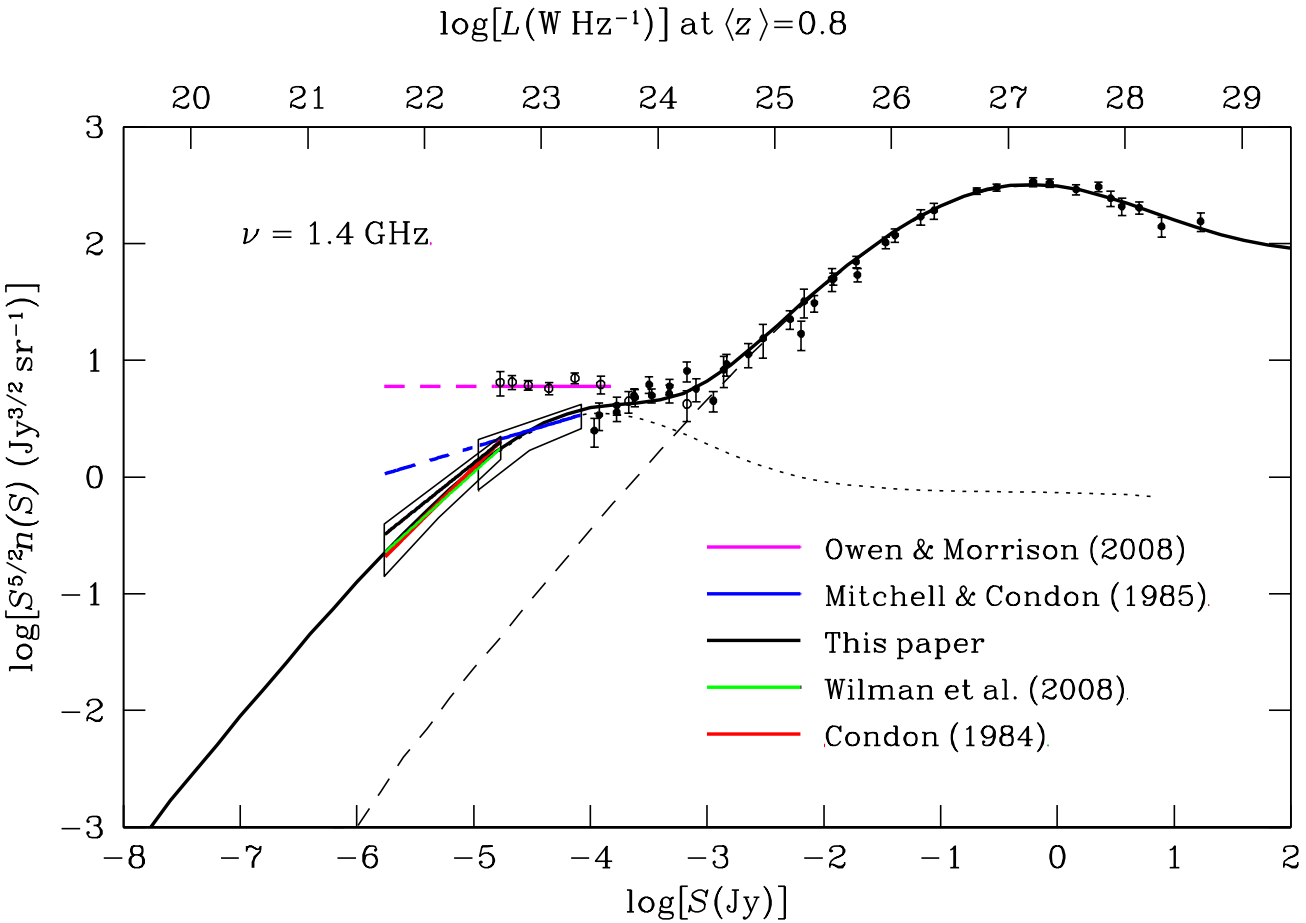


Two source populations dominate locally

Two populations (AGNs and star forming galaxies) With no major "new population" (energy source or spectral index) since 3CR



Source counts and "simple" evolution



10 × luminosity evolution + S∝(1+z)$^{-3.7}$ ➔ <z> ~ 0.8 shell, S∝L

Confusion-limited 3 GHz sky image, 8 arcsec resolution

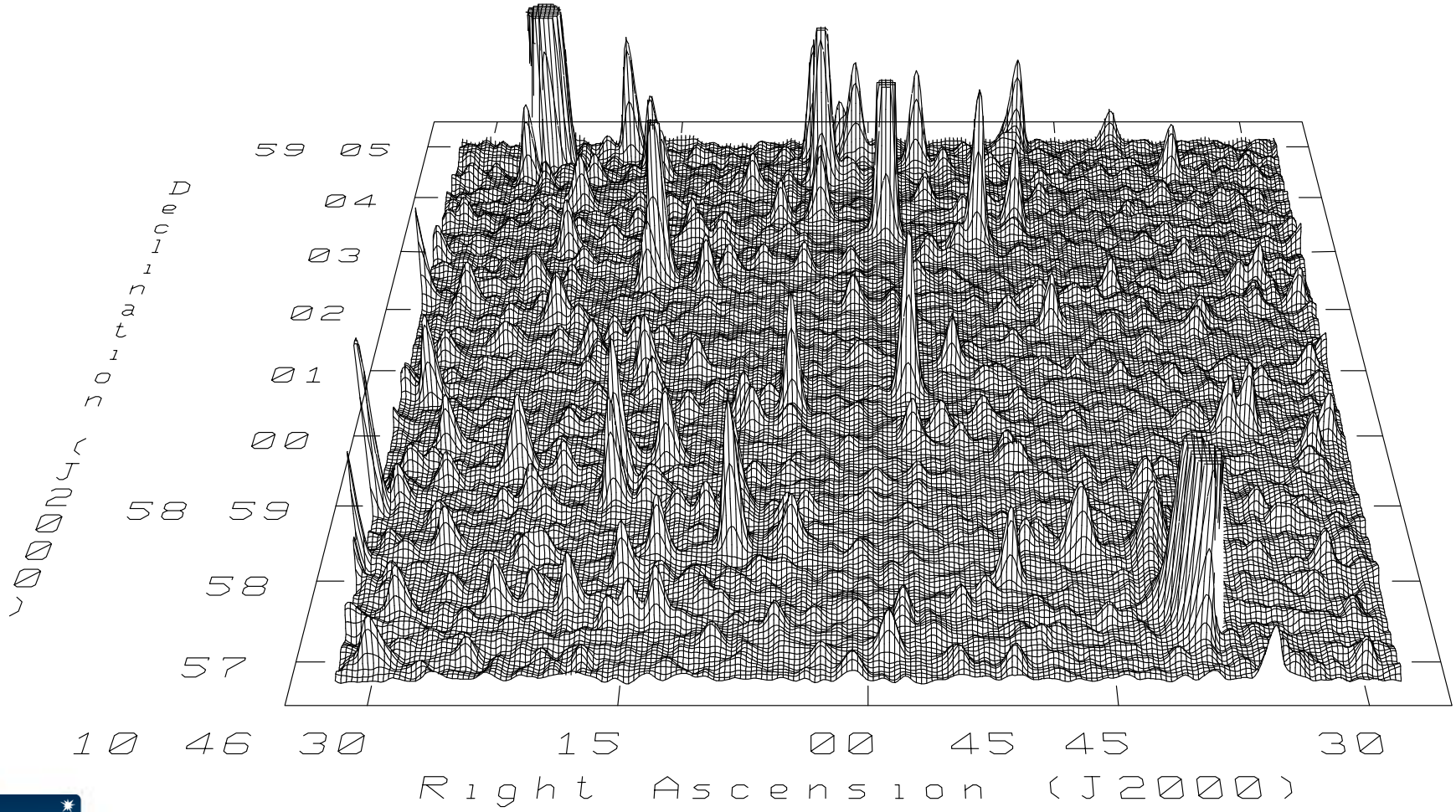
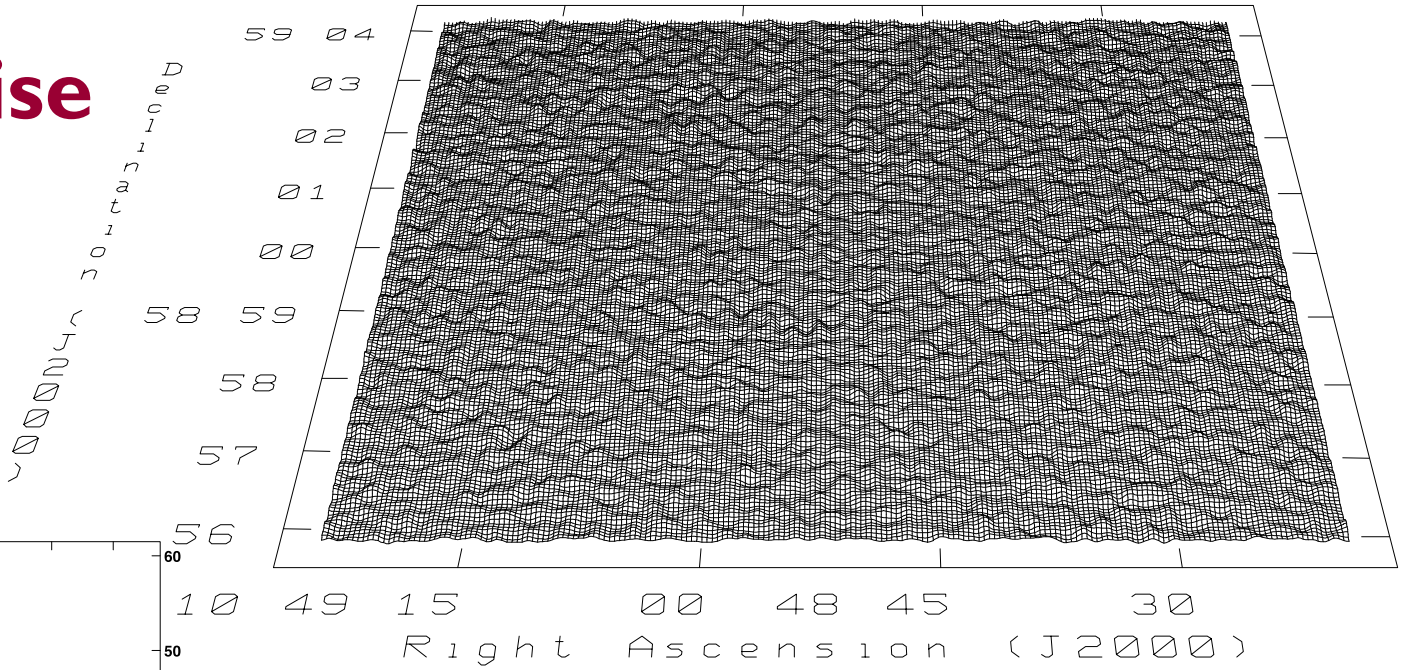
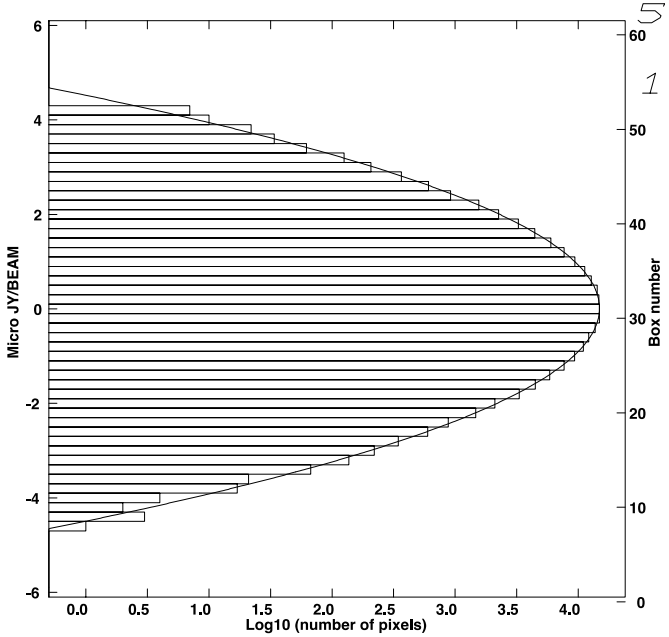


Image noise



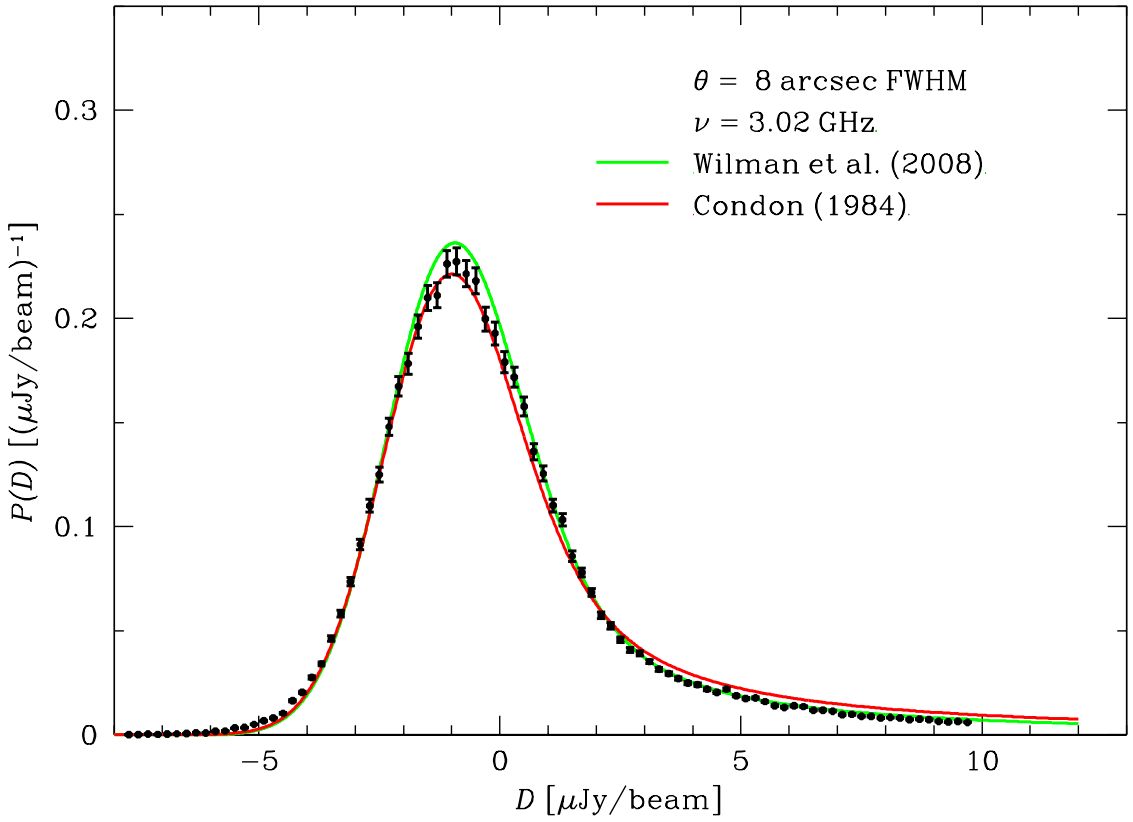


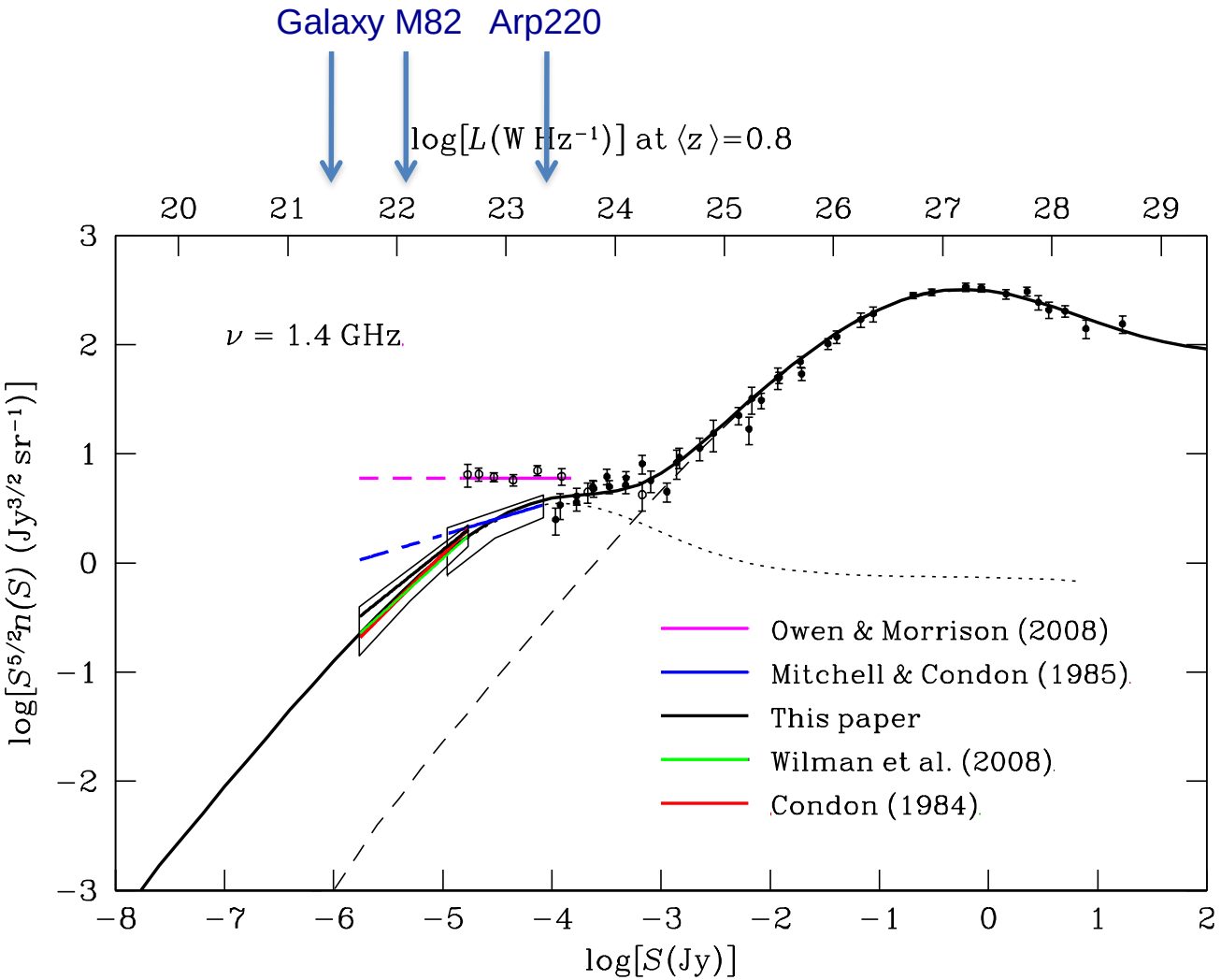
A perfect Gaussian with nearly zero mean and rms

$\sigma_n = 1.012 \pm 0.007$ μJy/beam after $\Delta\nu\,\Delta\tau \approx 10^{14}$

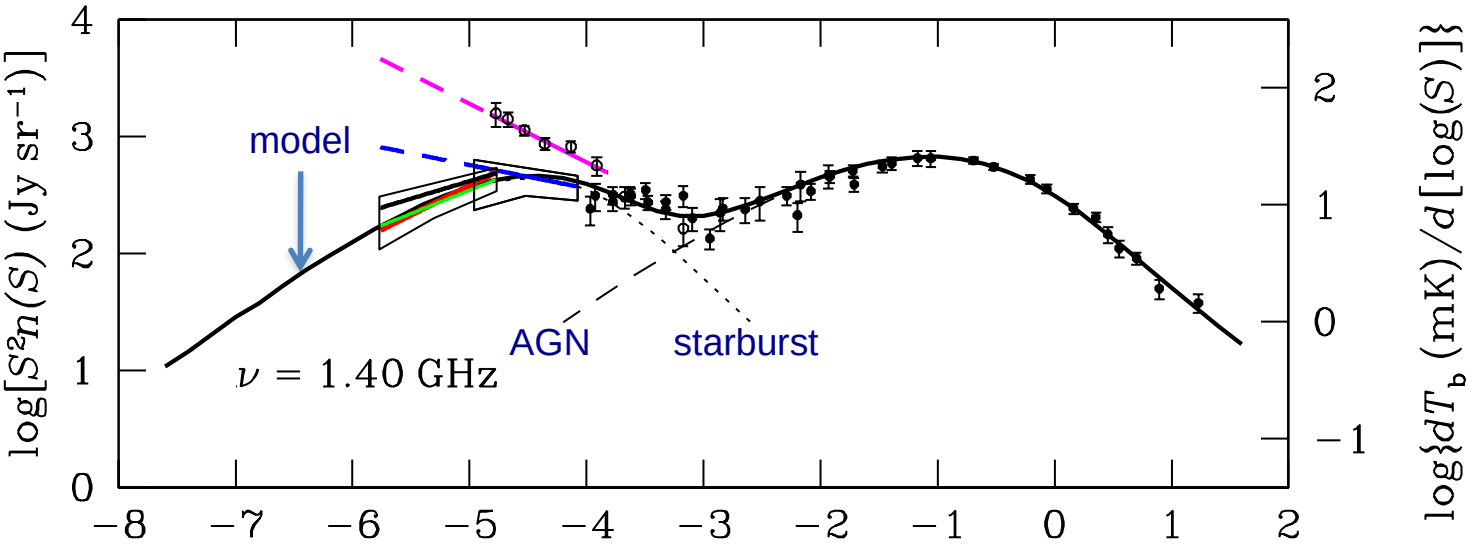
(1 μJy/beam = 2.1 mK)

Observed *P(D)* distribution and evolutionary models




Galaxy M82
Arp220
log[L(W Hz⁻¹)] at ⟨z⟩=0.8
20
21
22
23
24
25
26
27
28
29
ν = 1.4 GHz
log[S^{5/2}n(S)] (Jy^{3/2} sr^{-1})]
log[S(Jy)]
Owen & Morrison (2008)
Mitchell & Condon (1985)
This paper
Wilman et al. (2008)
Condon (1984)

Source counts and sky brightness

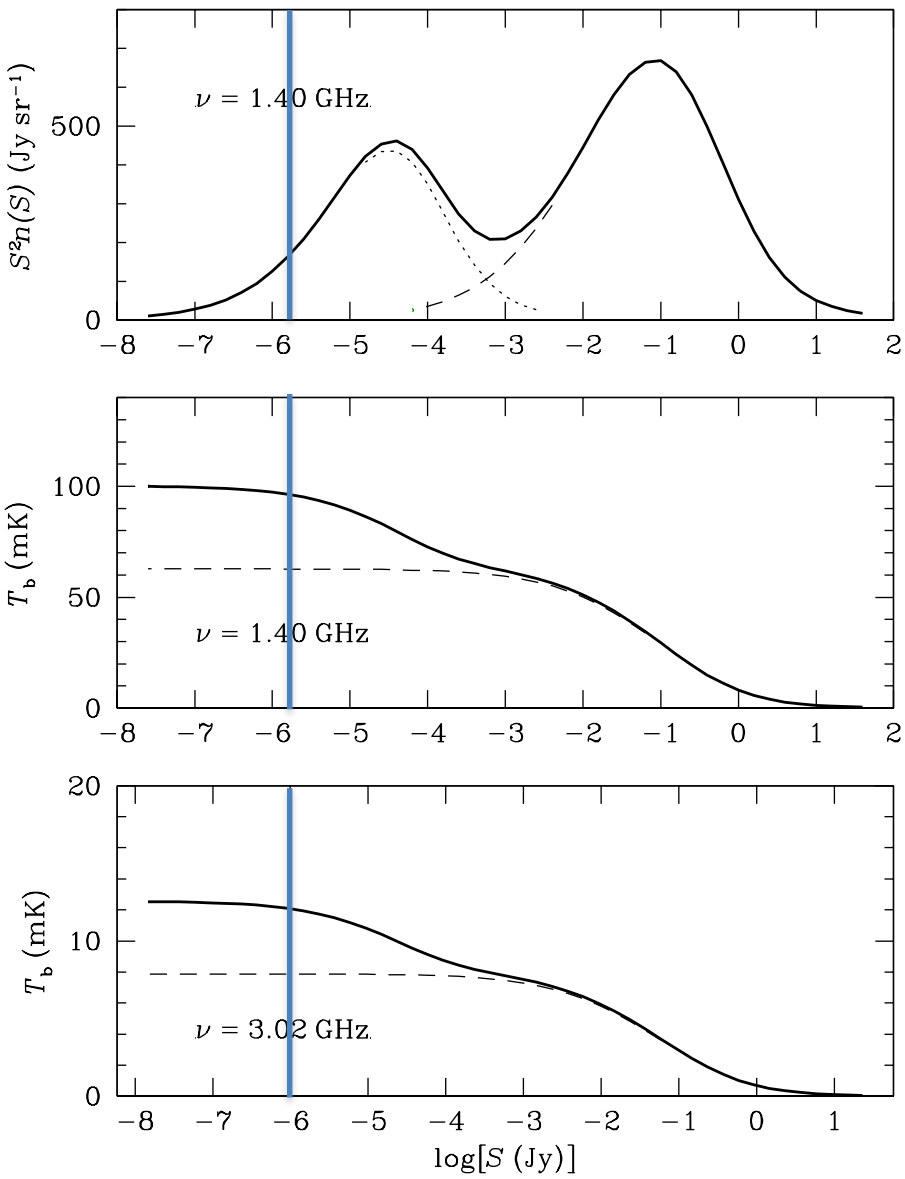


$$S = \frac{2k_{\mathrm{B}}T_{\mathrm{b}}\Omega}{\lambda^2} \qquad dT_{\mathrm{b}} = \frac{\lambda^2}{2k_{\mathrm{B}}} S^2 n(S) d\ln(S)$$

$$Sn(S)dS = \frac{2k_{\mathrm{B}}dT_{\mathrm{b}}}{\lambda^2} \qquad \left[\frac{dT_{\mathrm{b}}}{d\log(S)}\right] = \left[\frac{\ln(10)c^2}{2k_{\mathrm{B}}\nu^2}\right] S^2 n(S)$$

Source counts and sky brightnesses: linear ordinates

Current data limit



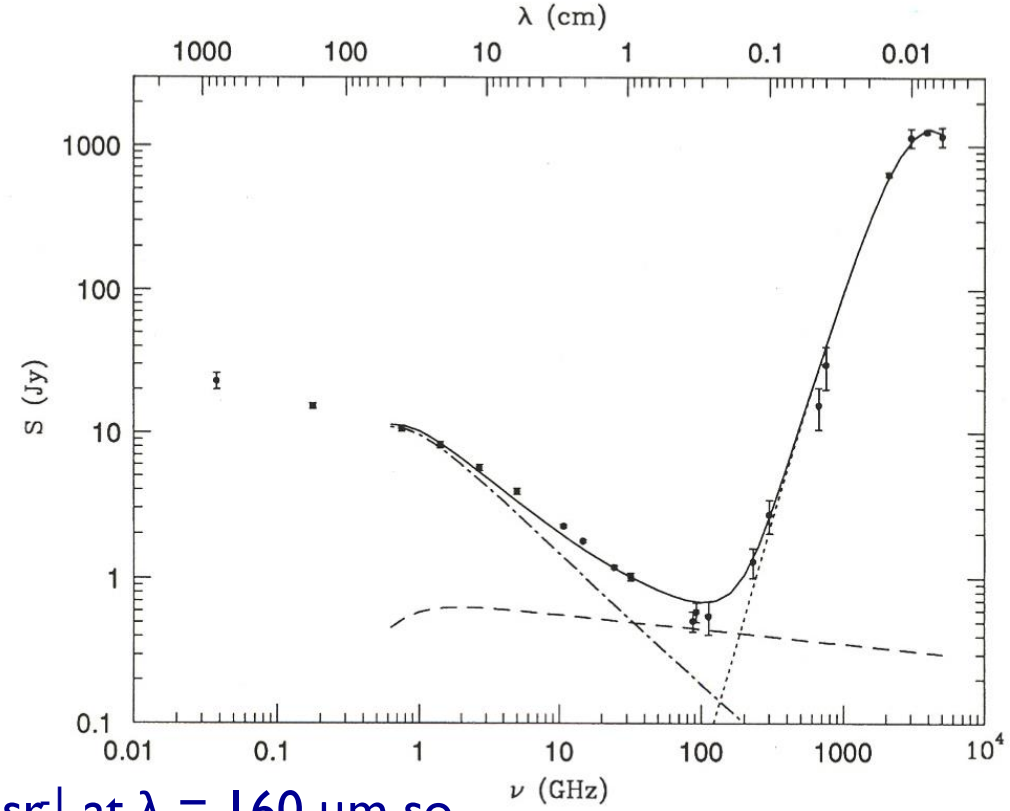
The radio and FIR backgrounds from star-forming galaxies

Local FIR/radio correlation

$\langle q \rangle = \log(S_{80\ \mu m})/\log(S_{1.4\ GHz}) = 2.3$

At z ~ 0.8, expect background

$q = \log(S_{160\ \mu m})/\log(S_{1.4\ GHz}) = 2.5$



COBE $\nu I_\nu \sim 1.3 \times 10^{-8}$ W m^2 sr^{-1} at $\lambda = 160\ \mu m$ so

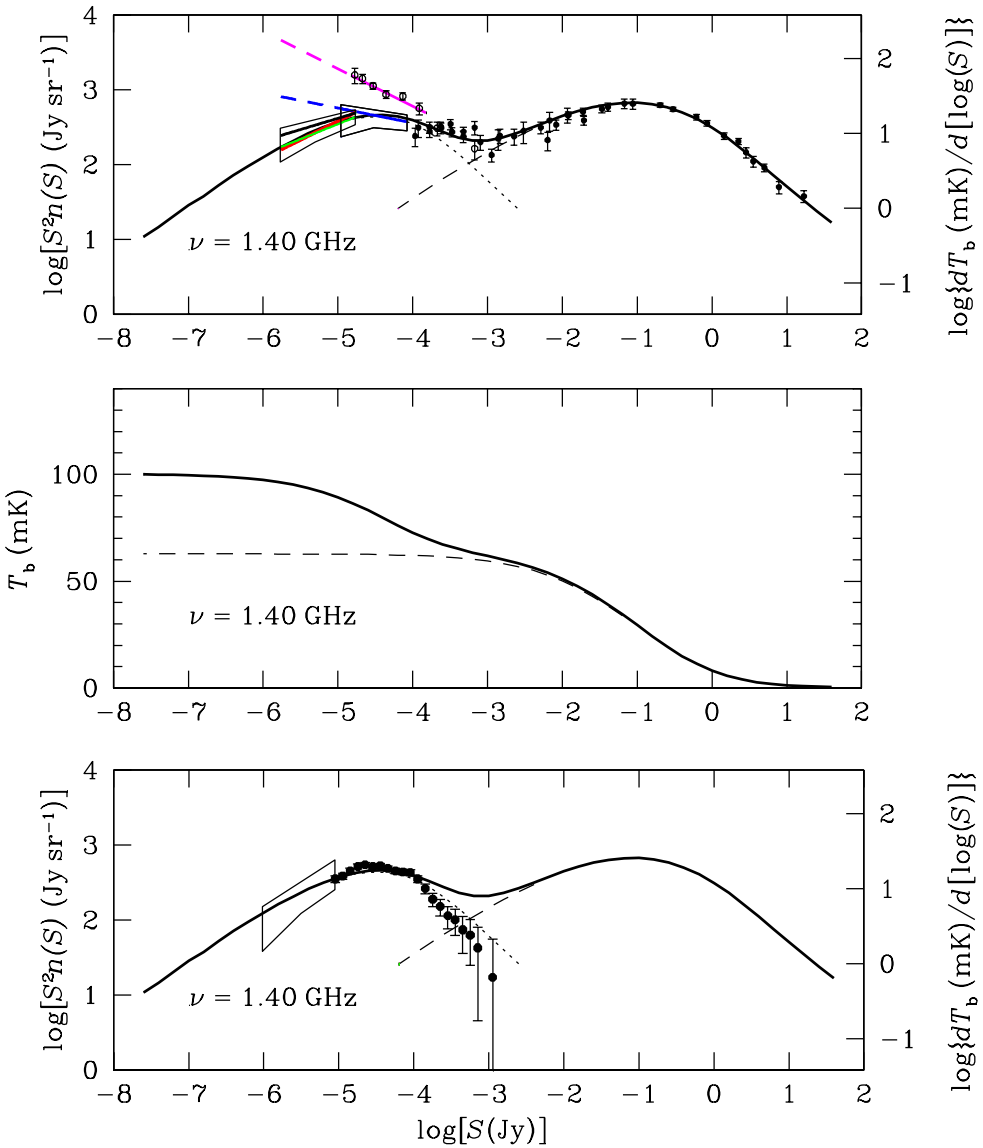
$I_\nu \sim 6.9 \times 10^{-21}$ W m^2 Hz^{-1} sr^{-1} ($\nu = 1.88 \times 10^{12}$ Hz)

Radio T = 37 mK at 1.4 GHz so $I_\nu \sim 2.2 \times 10^{-23}$ W m^2 Hz^{-1} sr^{-1}

Background $q \sim \log(6.9 \times 10^{-21} / 2.2 \times 10^{-23}) \sim 2.5$

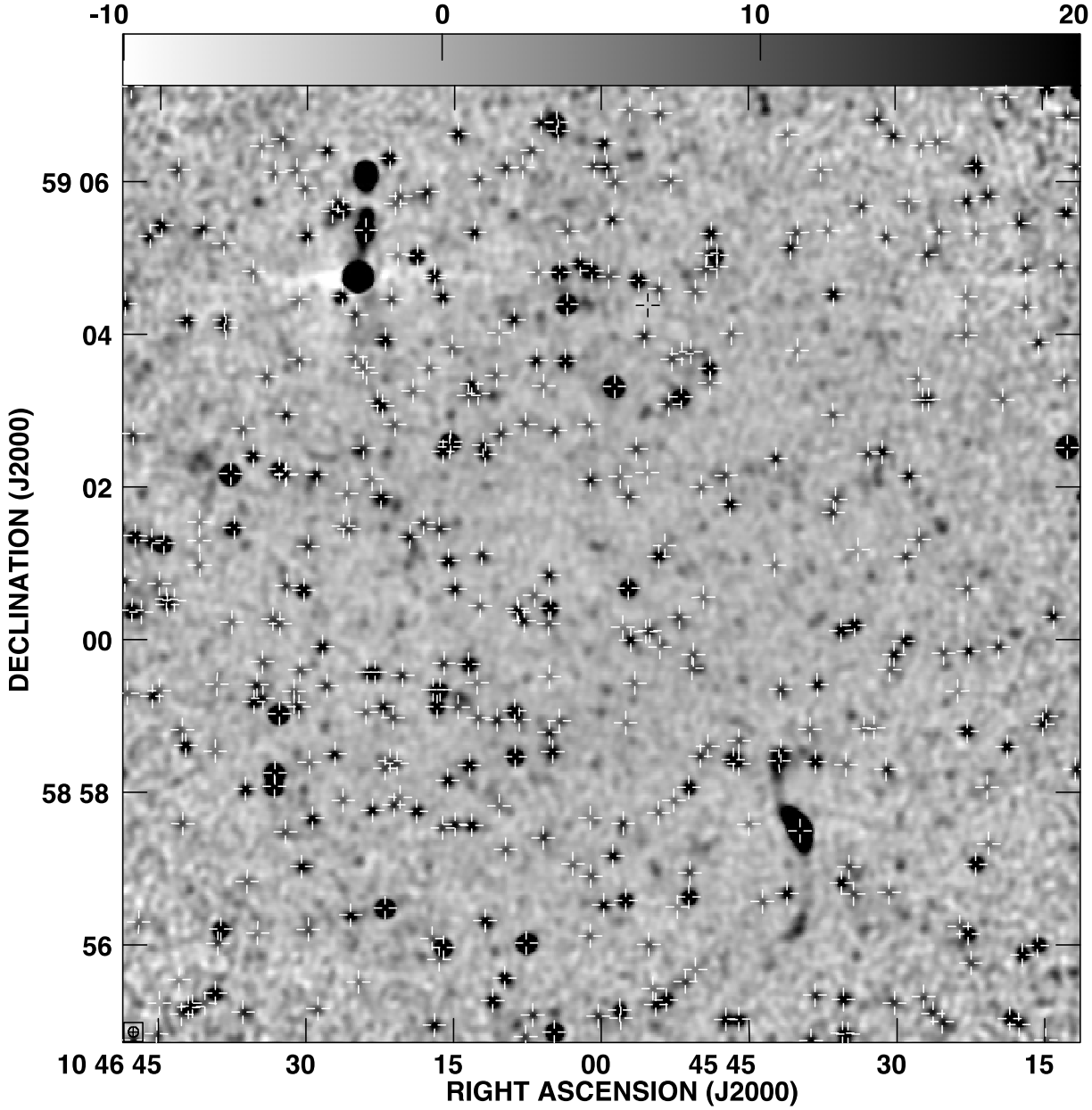
96% of the radio source background is resolved by $S_{1.4\ GHz} \sim 1.7\ \mu Jy$

Data points and box: 160 μm Herschel counts converted to 1.4 GHz by the FIR/radio ratio $q = \log(S_{160\ \mu m})/\log(S_{1.4\ GHz}) = 2.5$

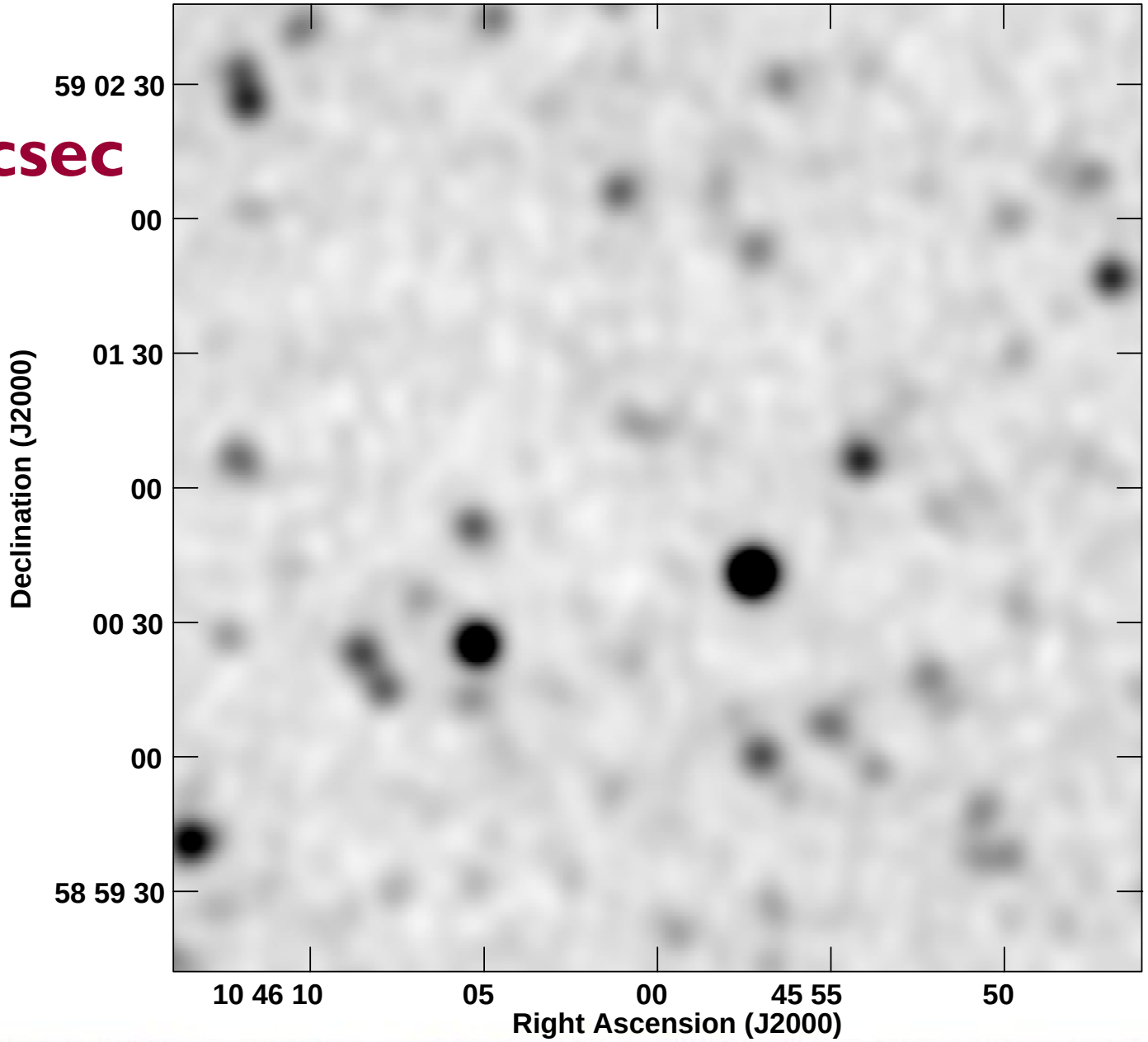


Gray scale:
JVLA μJy/beam
(3.02 GHz)

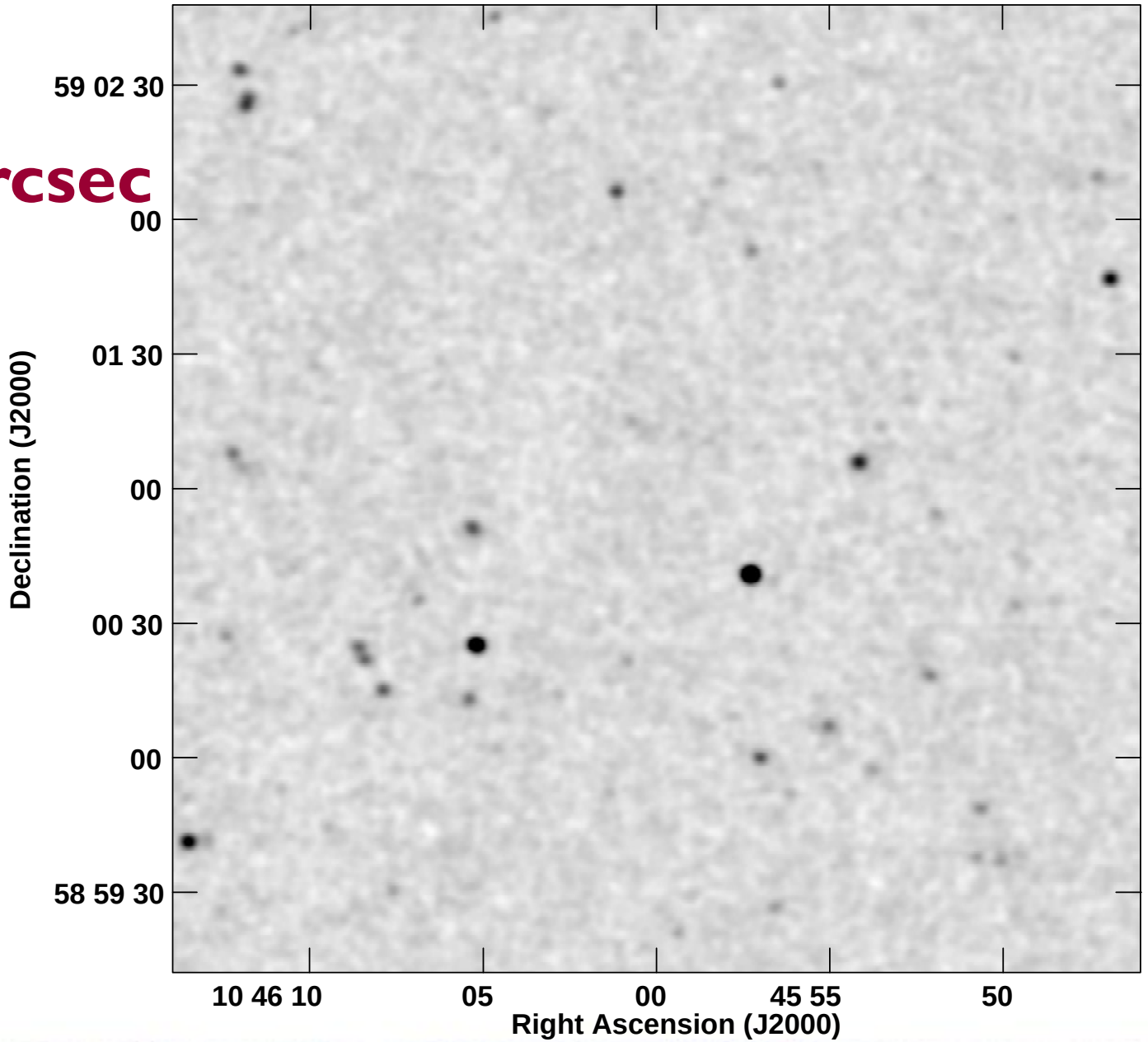
Crosses: Owen &
Morrison (2008)
sources



8 arcsec


59 02 30
00
01 30
00
00 30
00
58 59 30
Declination (J2000)
10 46 10
05
00
45 55
50
Right Ascension (J2000)

2.8 arcsec


59 02 30
00
01 30
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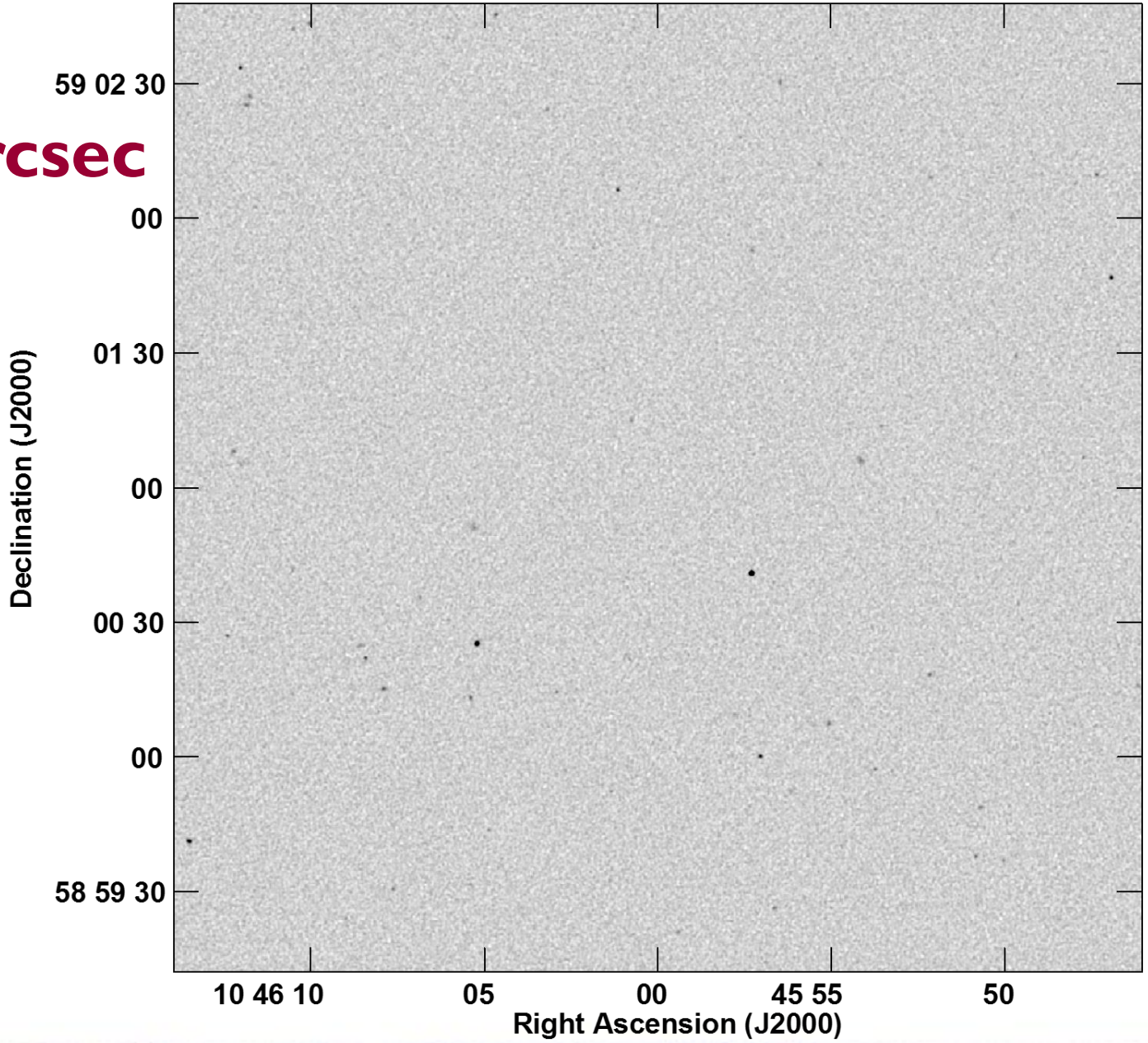
58 59 30
Declination (J2000)
10 46 10
05
00
45 55
50
Right Ascension (J2000)

0.65 arcsec


59 02 30
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58 59 30
Declination (J2000)
10 46 10
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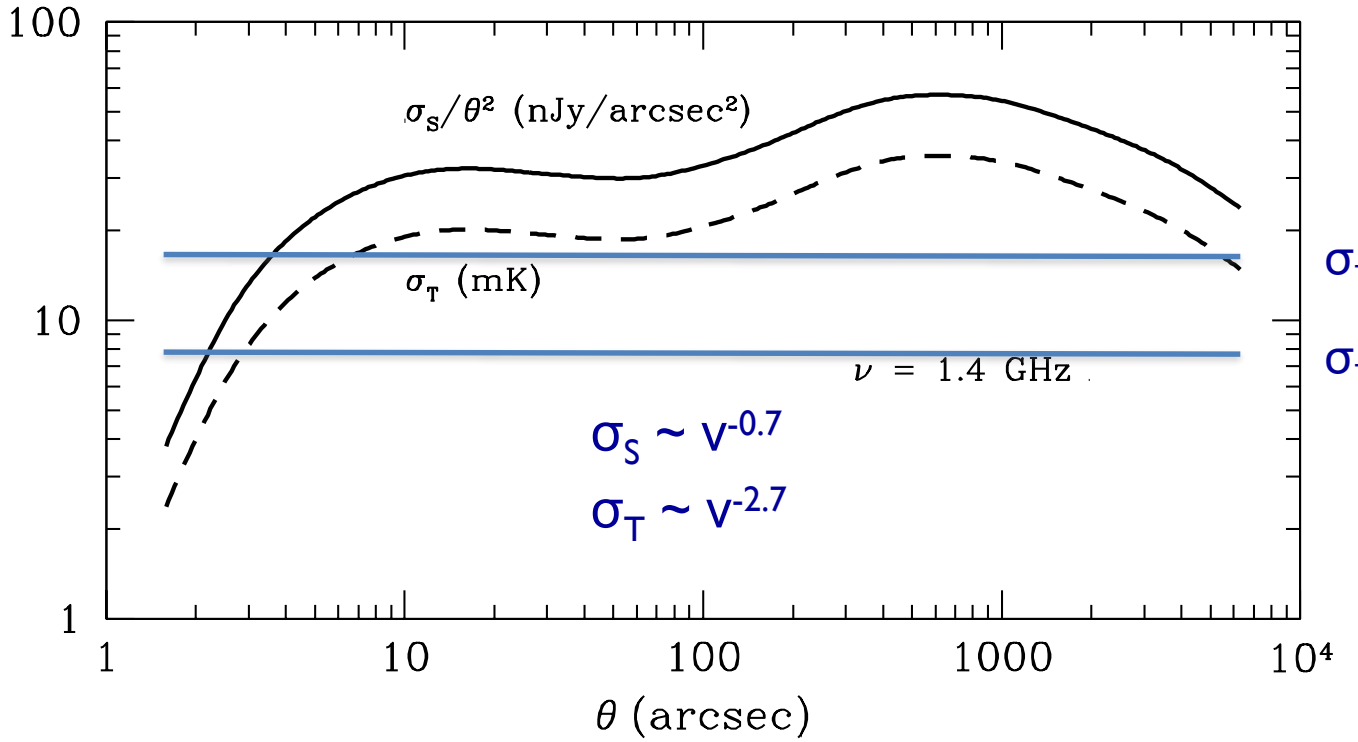
45 55
50
Right Ascension (J2000)

The source sky is bumpy: rms confusion ~ 0.3 of background from stronger sources



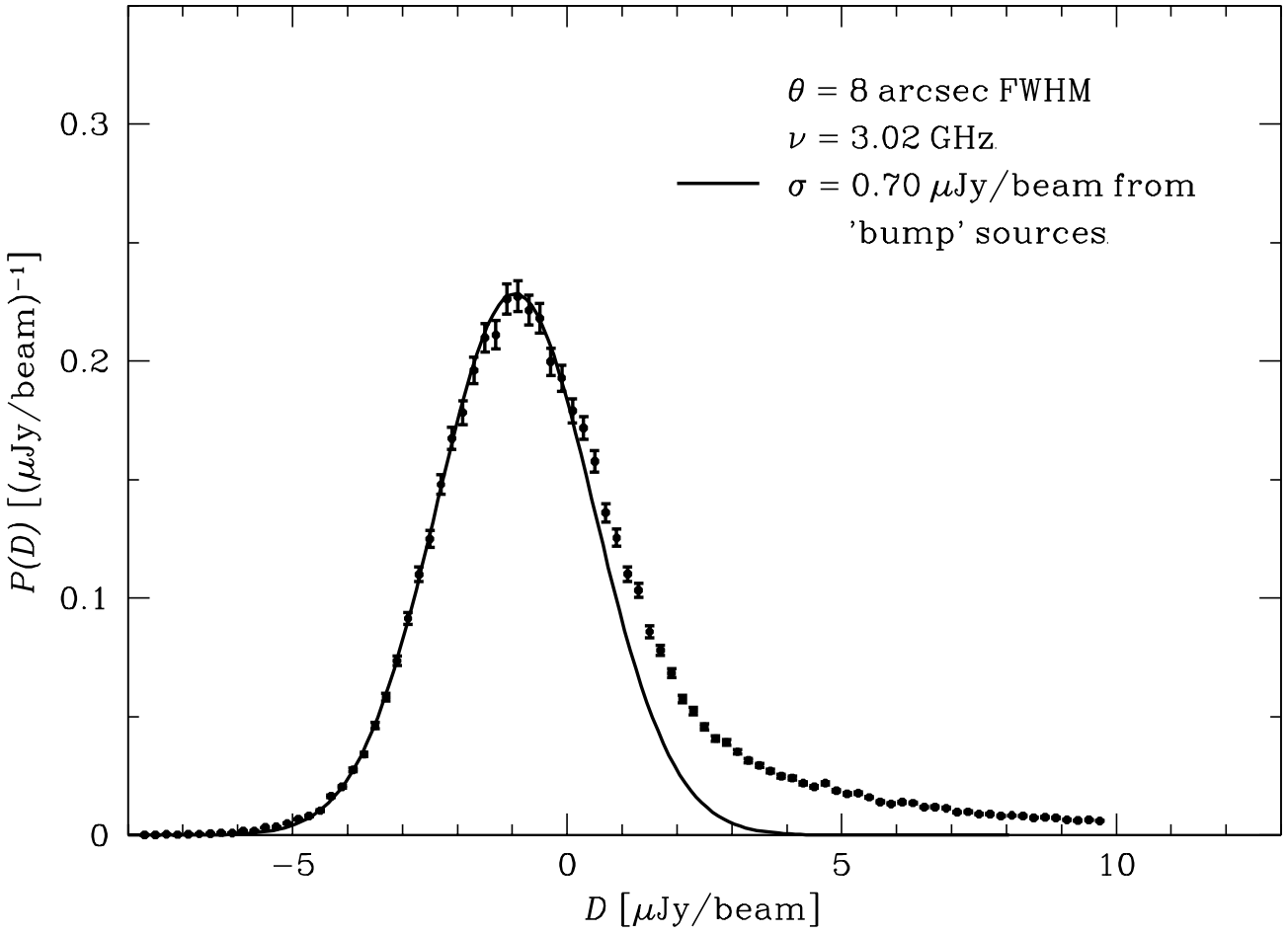
σ_T = 2 mK @ 3 GHz

σ_T = 1 mK @ 3 GHz

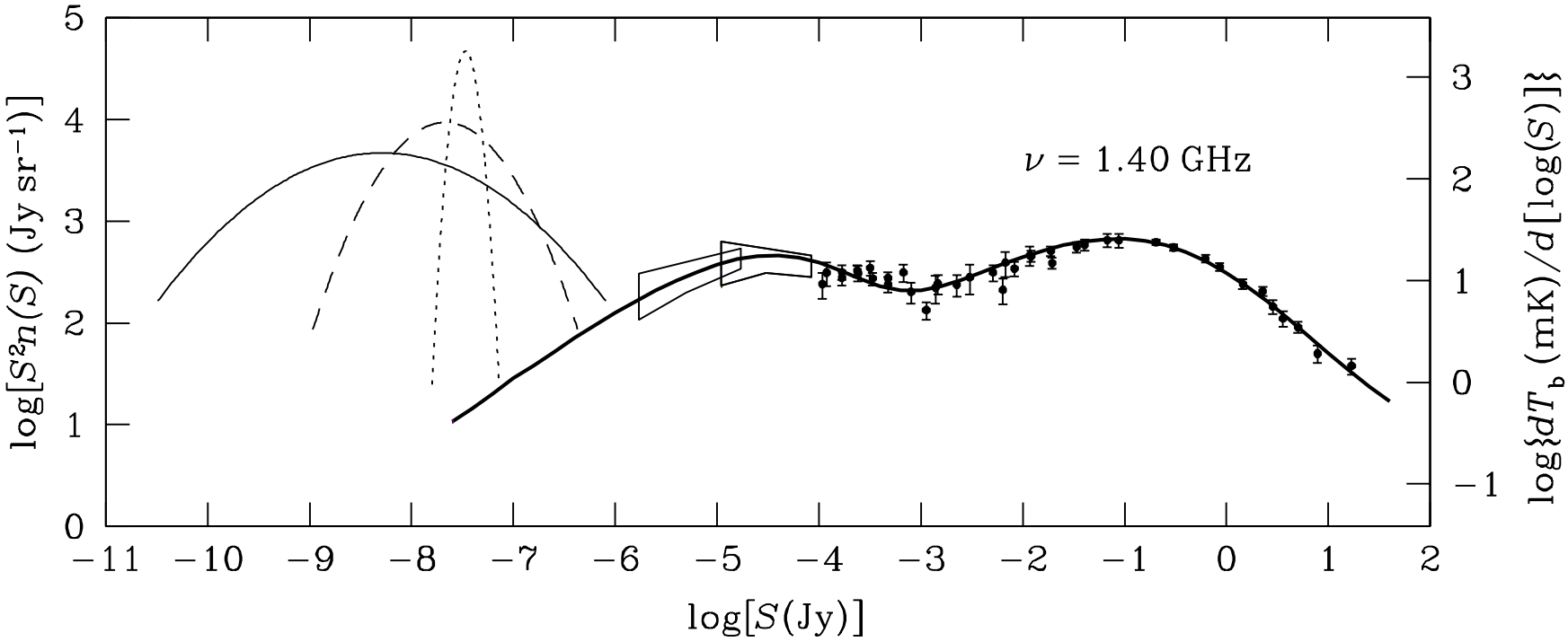
Example: θ = 8 arcsec FWHM at ν = 3 GHz so

$\sigma_S \approx 27 \times 8^2 \times (3/1.4)^{-0.7}$ nJy/beam ≈ 1.0 μJy/beam

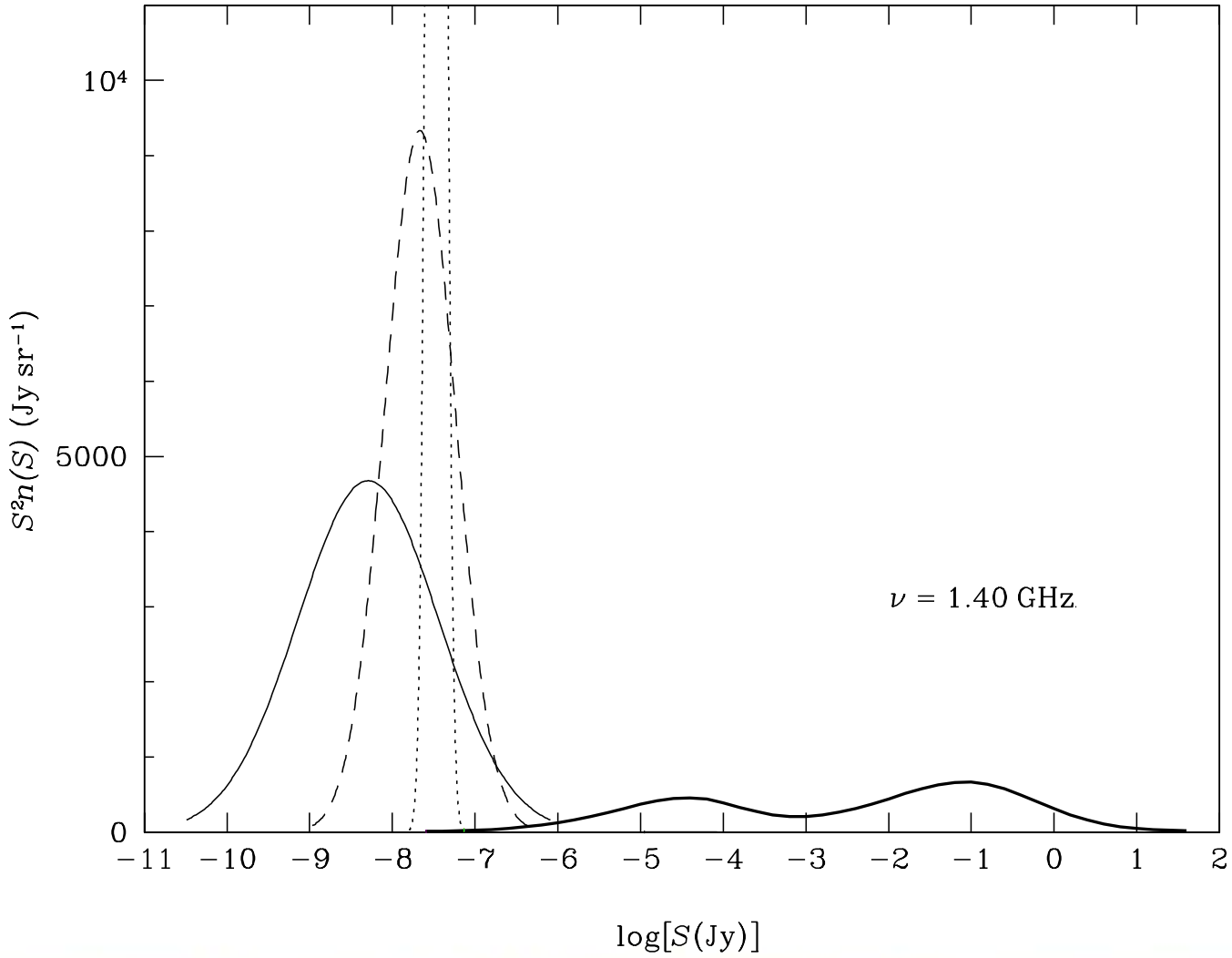
Gaussian confusion and ARCADE 2: many more sources than galaxies?



What new discrete sources could produce the ARCADE 2 background?



Previous plot with linear ordinate



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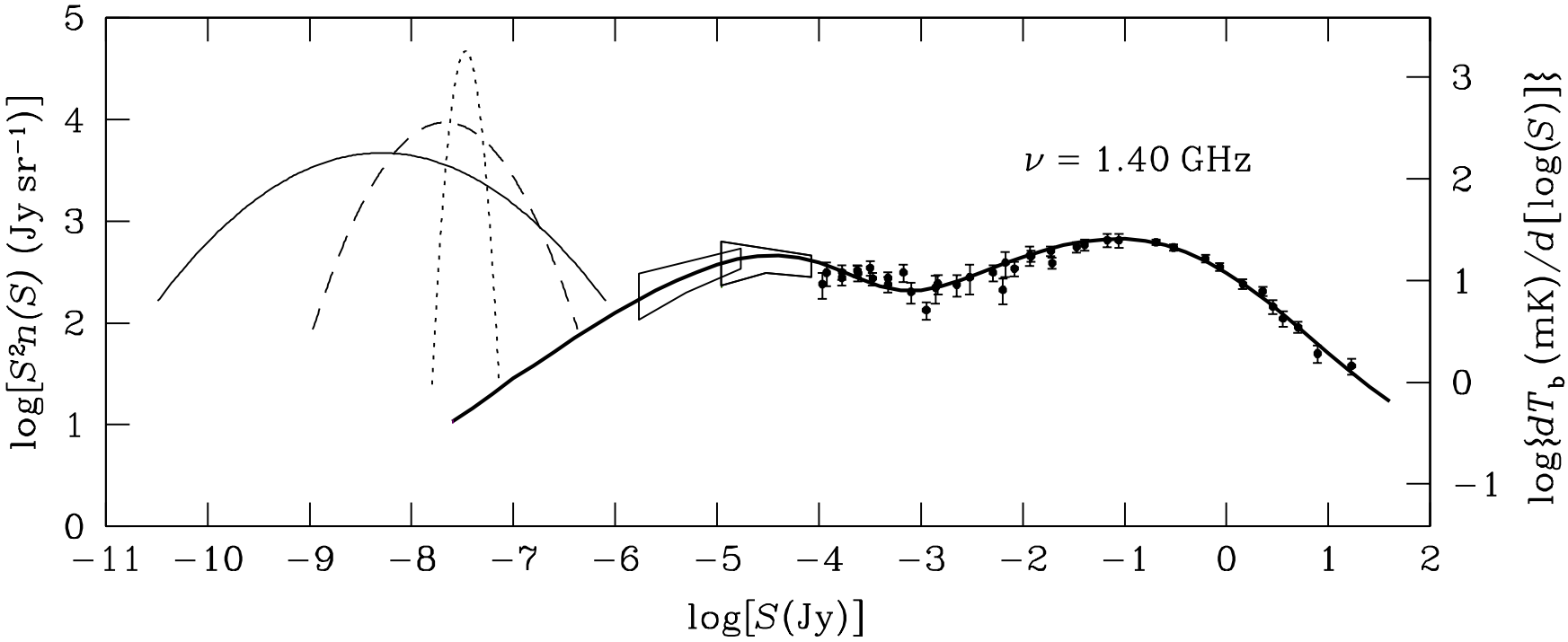
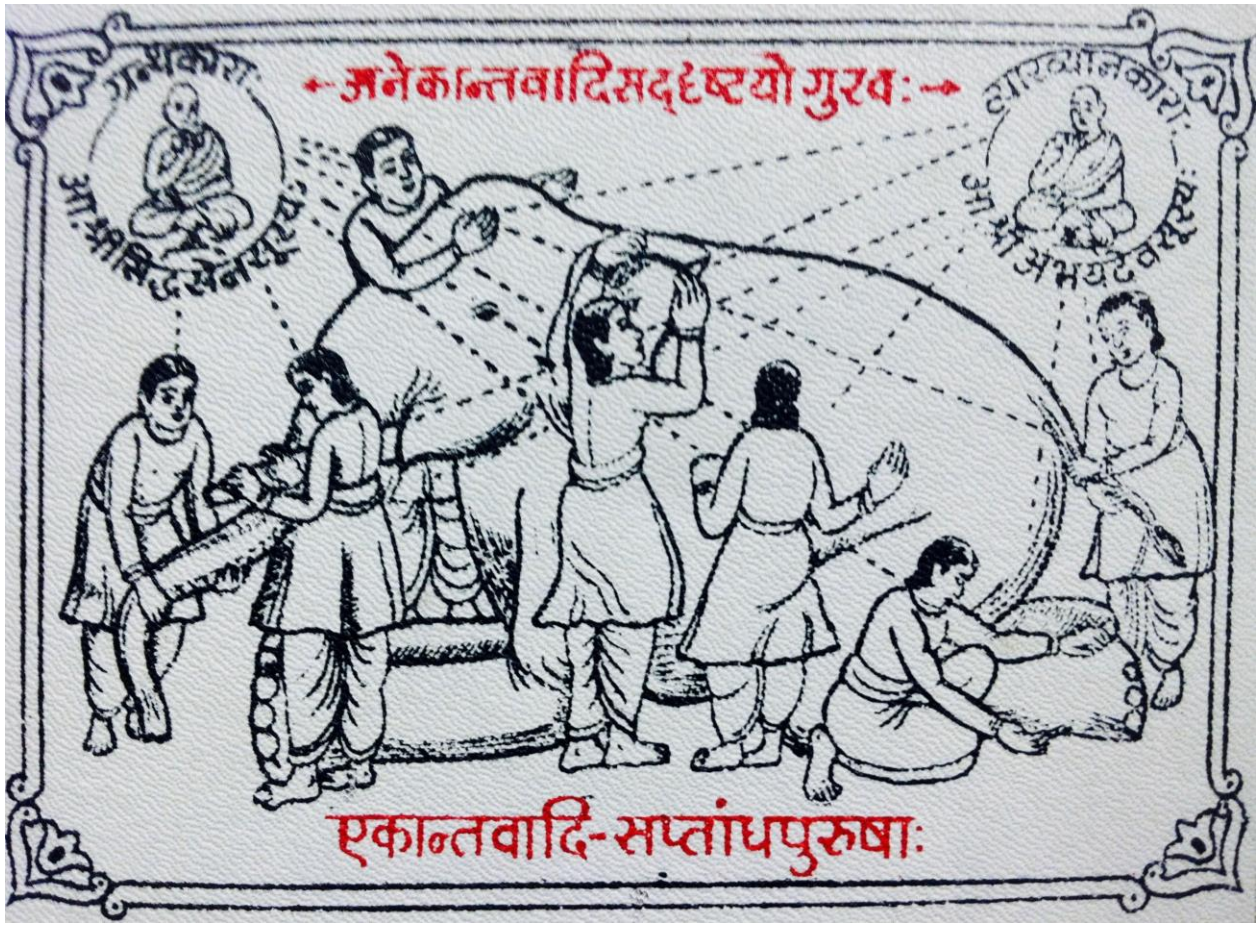


What can one blind man say about the elephant?

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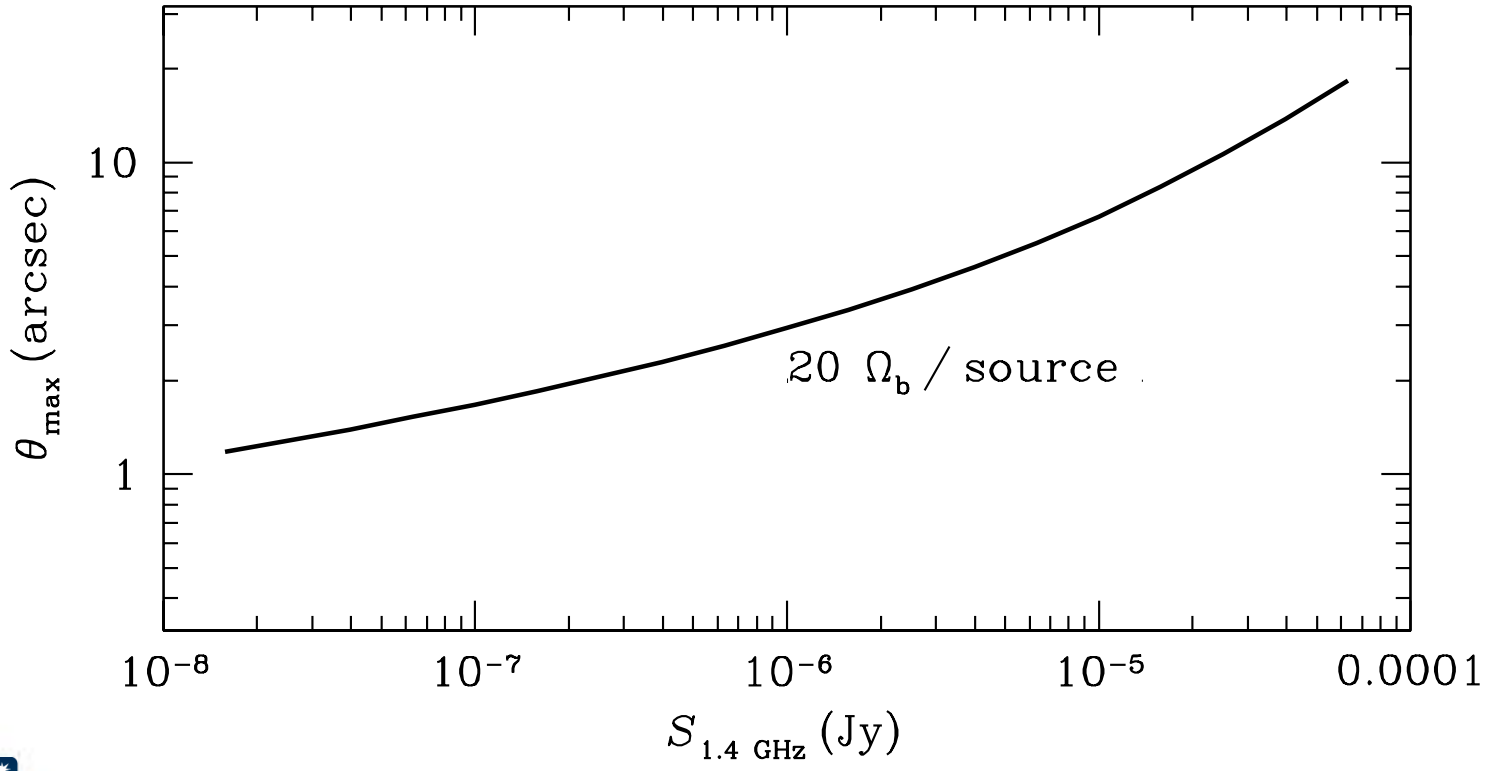
Summary:

1) The JVLA has resolved about 96% of the radio background produced by AGNs (63 mK at 1.4 GHz) and by star-forming galaxies (37 mK at 1.4 GHz).
2) The radio background produced by star-forming galaxies agrees well with the COBE 160 μm background and the FIR/radio correlation.
3) If the high ARCADE 2 background is real, it is too smooth to be produced by galaxies. If it consists of discrete sources, most are too faint to be detected individually even by the SKA.

(Condon, Cotton, Fomalont, Kellermann, Miller, Perley, Scott, Vernstrom, & Wall 2012, ApJ, 758:23)

Largest beamwidth θ_{max} for a given source detection limit

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No-noise *P(D)* distributions