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Source Count and Confusion Limit

Based on VLA 74MHz sky survey and Parkes catalog 1990 (80MHz and 178MHz)

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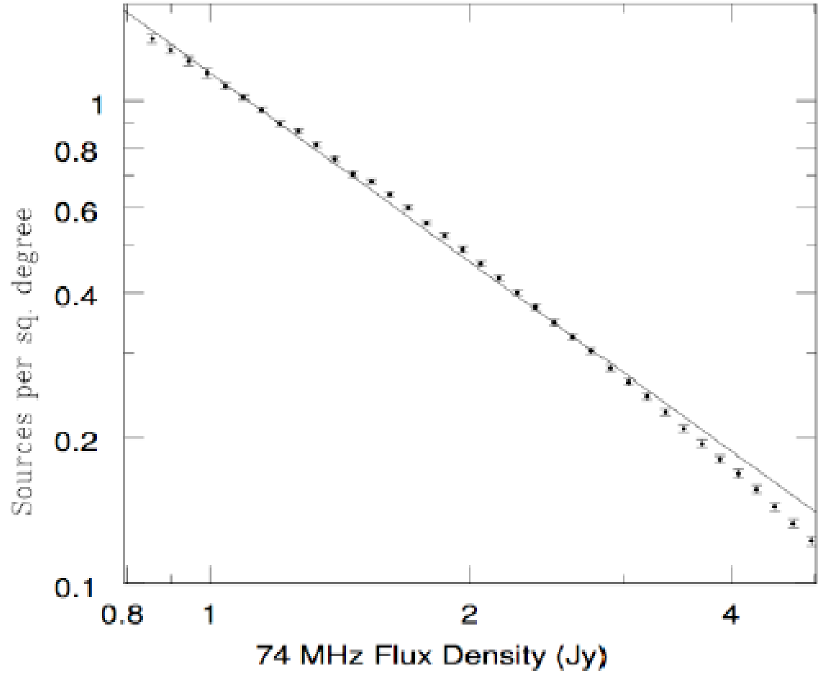
Source count estimation I : based on VLA 74 MHz Survey with many assumptions

Linear fit plot of the VLSS (A. Cohen 2004)



The source count can be represented by a power-law in Flux Density S:

$$N(>S) = C\,S^{\beta}$$

For VLA 74MHz Survey, C=1.14 β=-1.3:

$N(>S) = 1.14\,S^{-1.3}$ (in units of Jy and sq-degree)

Estimate number density power law at 1 MHz

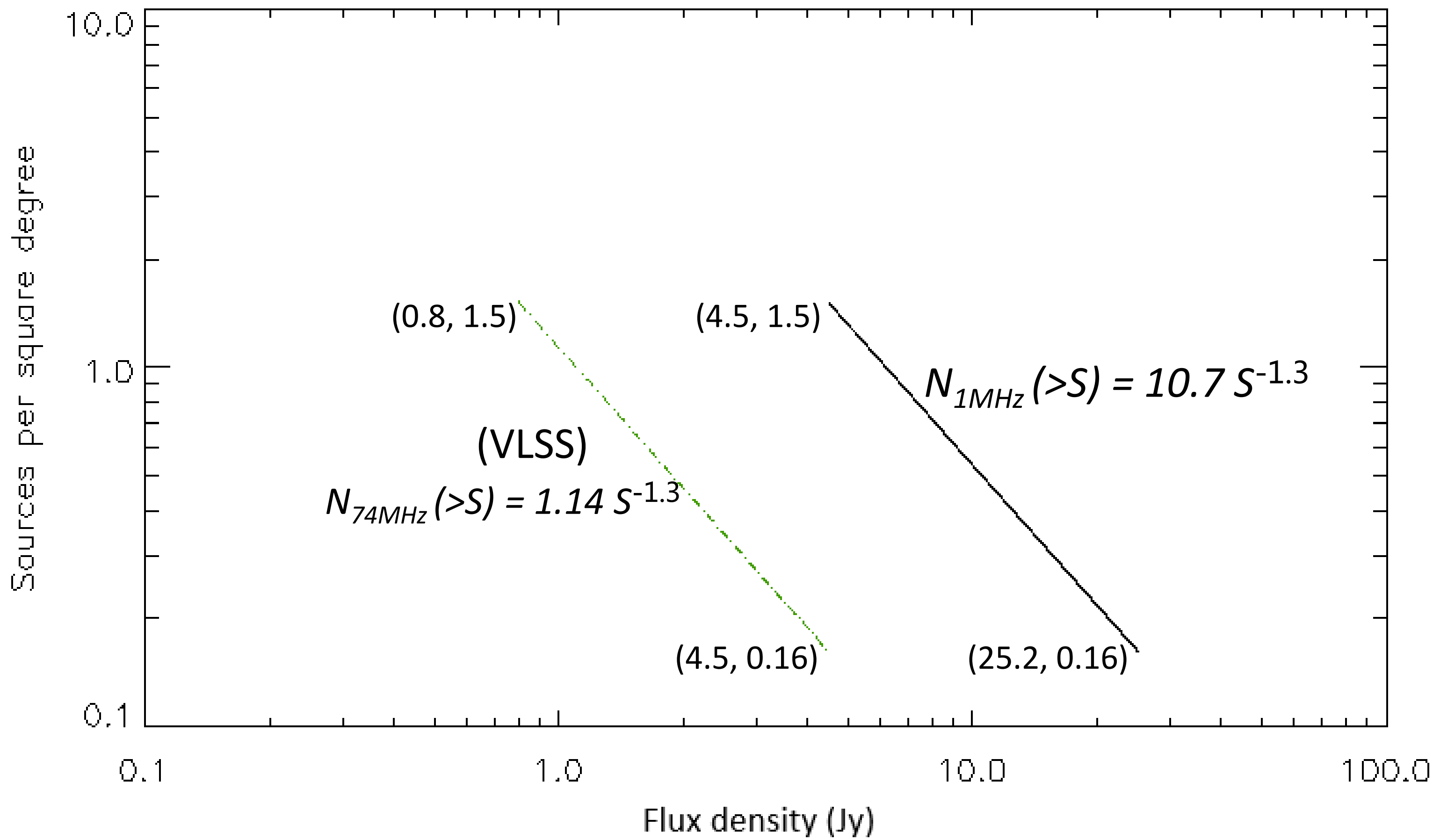
- From the VLSS number density power law at 74MHz：
  - 1.5 source / sq-degree at 0.8Jy
  - 0.16 source / sq-degree at 4.5Jy
- Assuming that the flux density follows a power-law of

$$S_\nu \propto \nu^{-\alpha}$$

- where the spectral index α is assumed to be 0.4 between 1MHz and 74 MHz (*E. B. Fomalont, AJ 1991*)
- The flux density range of the VLA linear fit plot: 0.8Jy to 4.5 Jy
  - A source of 0.8Jy at 74 MHz is 4.5Jy at 1MHz
  - A source of 4.5Jy at 74 MHz is 25.2Jy at 1MHz
- If we assume all sources detected at 74MHz band and at 1MHz band have 1-to-1 relation, we'd have：

$$N_{1MHz}(>S) = 10.7\, S^{-1.3}$$

The source number density for source count index β = -1.3



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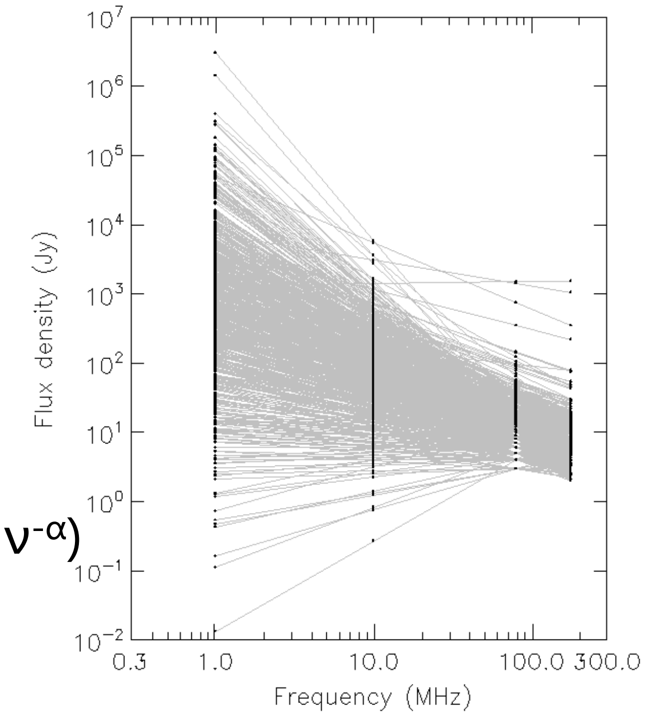
Source counts estimation II : based on Parkes Catalog 1990 (*PKSCAT90*)

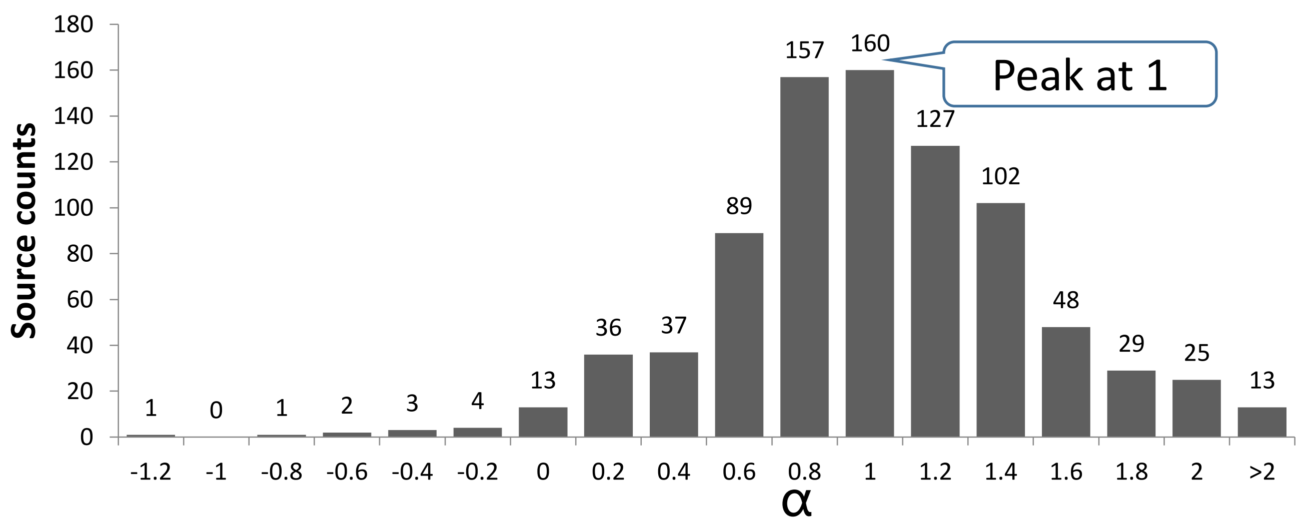
There are 8264 sources in PKSCAT90. 847 sources have flux density at both 80MHz and 178MHz.

We assume the spectral index remains constant between 1MHz and 178MHz for all these sources:

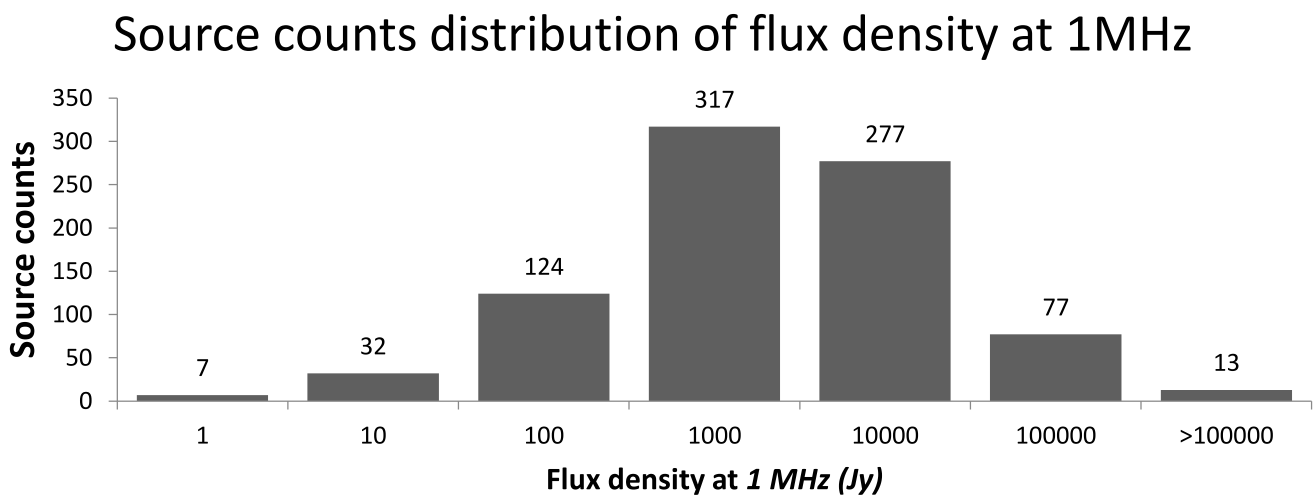
$$S_\nu \propto \nu^{-\alpha} \quad \alpha = -\frac{\log(S_{80\,MHz}) - \log(S_{178\,MHz})}{\log(80) - \log(178)}$$



Source counts distribution of spectral index α ($S_\nu \propto \nu^{-\alpha}$)



Extrapolated 1 MHz flux density

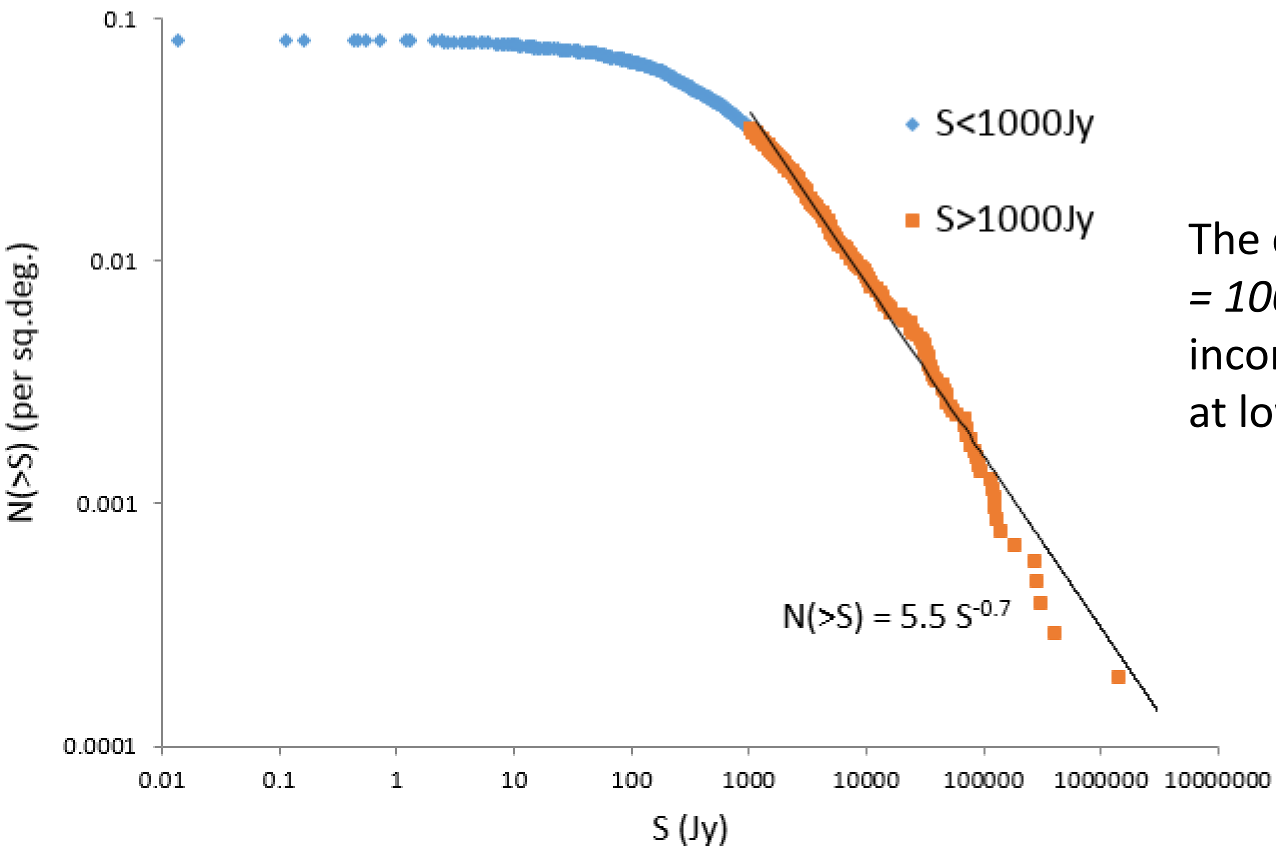


Source counts in different flux density bins at *1 MHz*

Flux Density	Source counts	Percentage	Source per square deg.	Whole Sky Sources
$>10^4$	90	11%	0.01	**360**
$10^3 - 10^4$	277	33%	0.03	**1108**
$100 - 10^3$	317	37%	0.03	**1268**
10 – 100	124	14%	0.01	**496**
1 – 10	32	4%	0.003	**128**
<1	7	1%	0.0007	**28**
Total	847	100%	0.08	**3388**

95% sources for S > 10 Jy 99% sources for S > 1 Jy

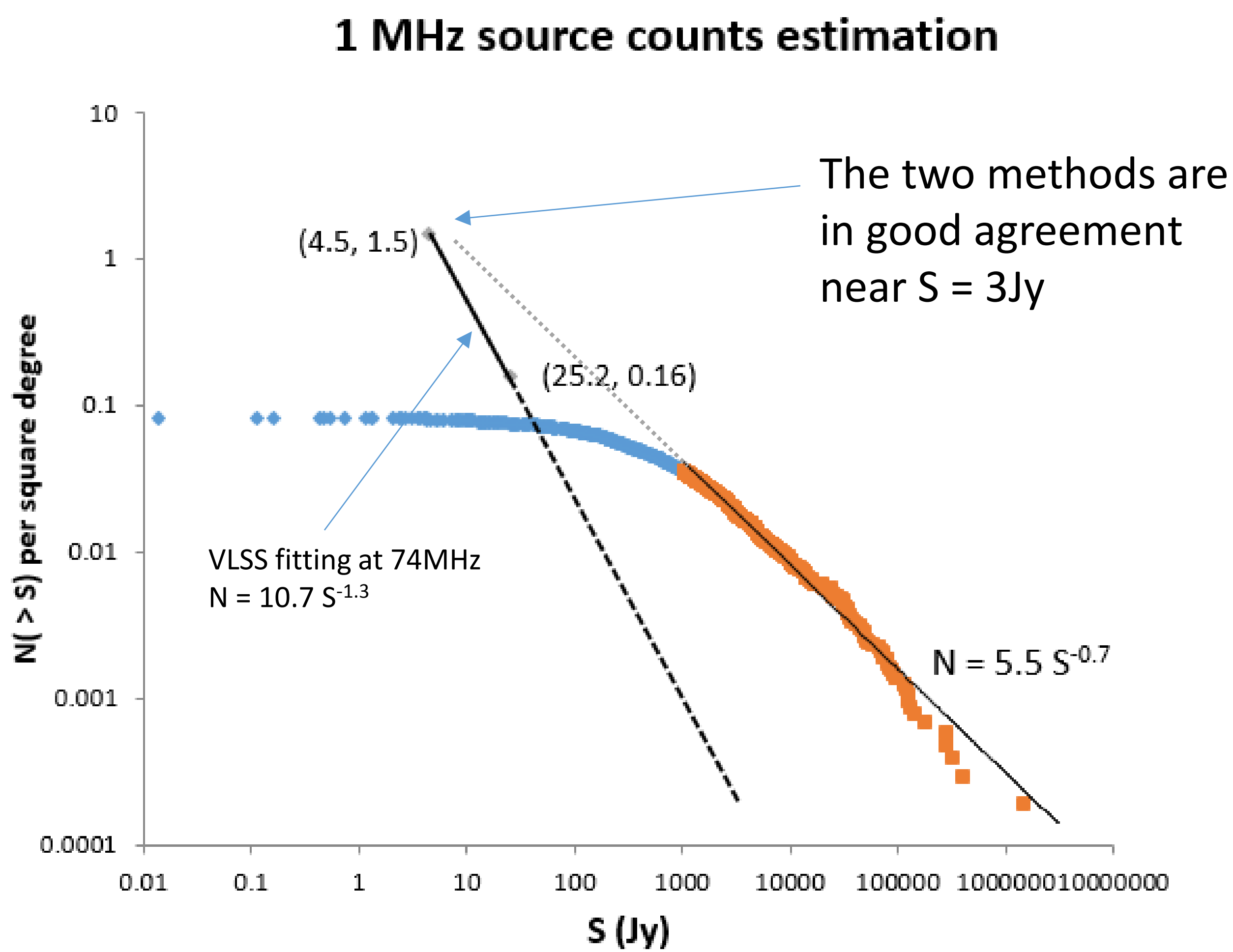
Power-law fitting of source counts vs flux density at 1MHz based on *PKSCAT90*



The curve turns sharply near *S = 1000 Jy.* It may be due to incompleteness of the catalog at low flux density.

Power-law fitting for *S > 1000 Jy* yields: $N(>S) = 5.5\ S^{-0.7}$

Comparison of the two methods



DRAO 10MHz Survey (Caswell 1976)

- Covers large portion of the Northern sky
- Beamwidth ~2 degree

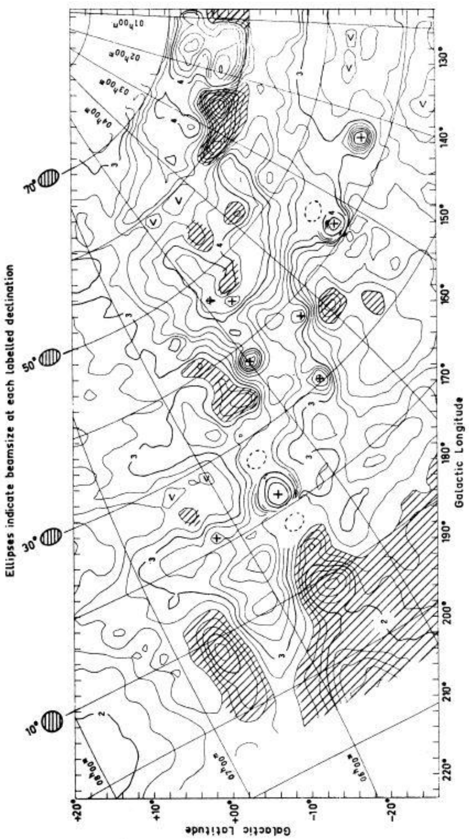
Measurements on sources for which Bridle & Purton measured intensities of more than 300Jy (360 Jy after the revision of their flux density scale suggested by Roger, Bridle & Costain 1973), on other sources visible on the contour map, and on three weaker sources not measured by Bridle & Purton. (*Caswell 1976*)

N(S > 360 Jy) = 26

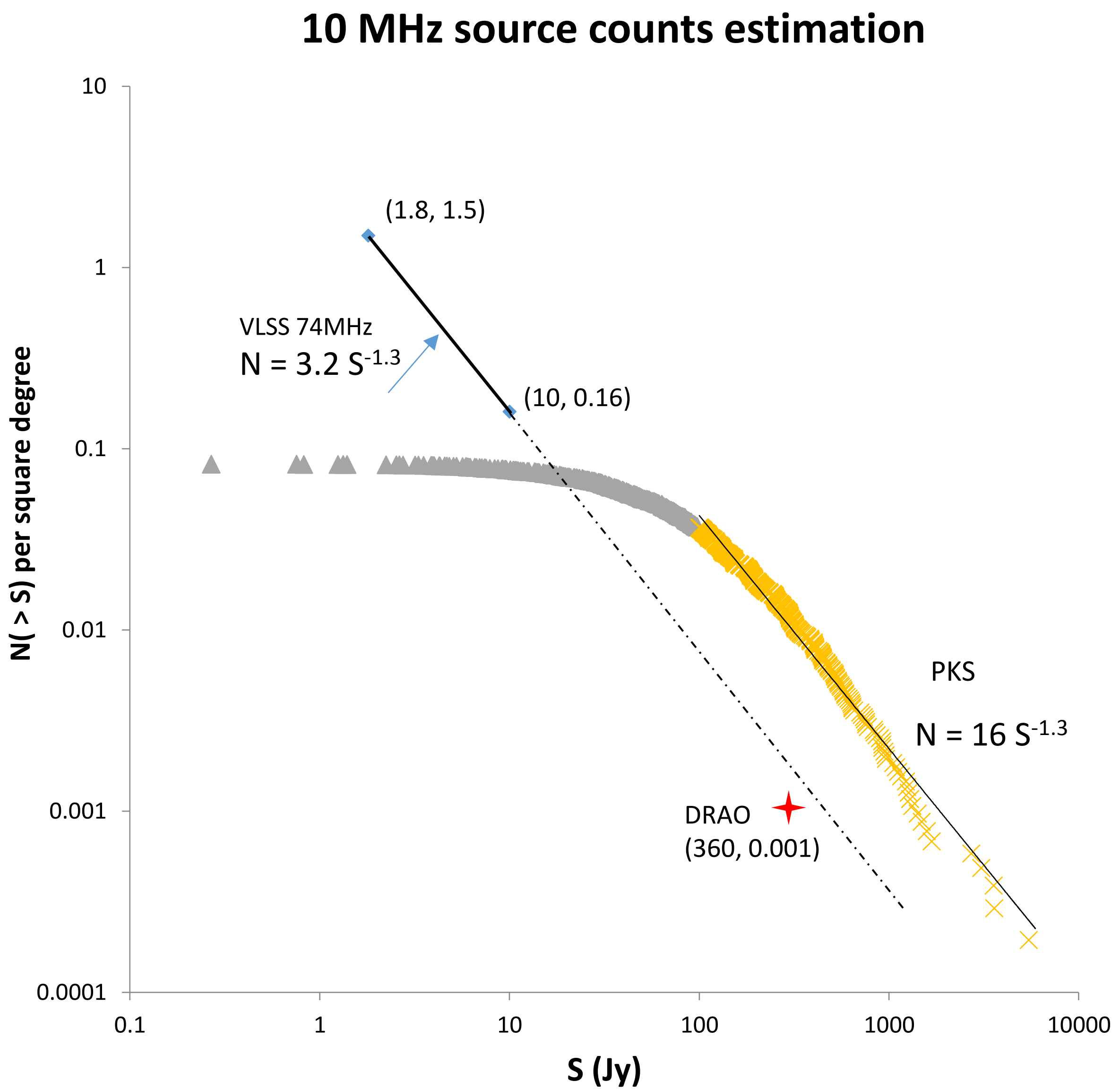
Full sky source >52
(0.001 sources / sq-deg)

10-MHz flux densities of discrete radio source

1950 coordinates RA h m	Dec. (°)	Common name	BP flux density* (Jy)
00 38	+09·9	3C 18	—
00 52	+68·2	3C 27	192
01 06	+13·1	3C 33	588
01 33	+20·7	3C 47	312
02 20	+42·8	3C 66	672
02 29	+34·5	3C 68·1	156
02 31	+31·3	3C 68·2	222
02 55	+05·9	3C 75	456
03 07	+16·9	3C 79	252
03 16	+41·3	3C 84	1704
03 31	−1·2	3C 89	672
04 15	+37·9	3C 111	432
04 33	+29·6	3C 123	960
04 45	+44·9	3C 129	324
04 50	+31·4	3C 131	564
04 57	+46·7	HB9	960
05 01	+38·0	3C 134	624
05 31	+22·0	Crab nebula	5580
06 10	+26·1	3C 154	114
06 14	+22·7	IC 443	480
07 10	+11·9	3C 175	210
07 21	+15·6	3C 177	—
07 23	+12·5	4C 12·29/30	396
07 26	+24·7	4C 24·15	276
08 10	+48·4	3C 196	408
08 55	+10·5	†DB 61	396
09 08	+38·1	4C 38·27	312
09 17	+45·8	3C 219	396
09 19	+31·4	4C 31·33	105
09 45	+07·6	3C 227	672
09 58	+29·0	3C 234	408
11 06	+25·2	3C 250	360
11 42	+19·9	3C 264	756
11 43	+31·8	3C 265	—
12 28	+12·7	Virgo A	9960
12 57	+28·2	Coma cluster	432
14 20	+19·8	3C 300	288
15 02	+26·2	3C 310	600



Comparison to VLA and PKS extrapolated to 10MHz



Confusion effect

Confusion occurs when there is on average one source in every *m* synthesized beam areas:

$$\theta^2 m N(s) \sim 1$$

(The standard rule of thumb) 1/30 of a source per beam is regarded as the limit of identifying and measuring individual sources(Hogg, AJ 2001).

Taking $\beta = -1.3, \mathrm{m} = 30$

The source counts can be represented by a power-law:

$$N(S) = CS^{\beta}$$

Combining and setting S to be equal to the confusion limit:

$$\sigma_c = (\theta^2 m \mathrm{C})^{-1/\beta}$$

Confusion limit from VLSS

If the maximum baseline is *100 km*, the resolution is ~*10 arcmin*. We have the following confusion limit based on number density estimation from VLSS:

$$\sigma_c = 5.6\,Jy \quad (\mathrm{C} = 10.7, \beta = -1.3, \mathrm{m} = 30)$$

From the next page, three antennas with 0.1MHz bandwidth are sufficient to achieve the confusion limit (5.6Jy) in 90 days.
There is not a lot of room to improve sensitivity to have more than 3 antennas at 1MHz.

Number of sources in *PKSCAT90* that can be detected with different survey parameters at *1MHz*

Number of antenna	Bandwidth (MHz)	Sensitivity (Jy)	Percent of 847 sources
2		7.9	97%
3	0.1	4.4	98%
10		1.1	99%
2		2.4	99%
3	1	1.3	99%
10		0.37	99%

In the calculations we assume that: 2 polarizations for each antenna, 90 days observation period , 1/3 duty cycle (observe only when shielded), and 1-bit sampling (36% sensitivity loss).

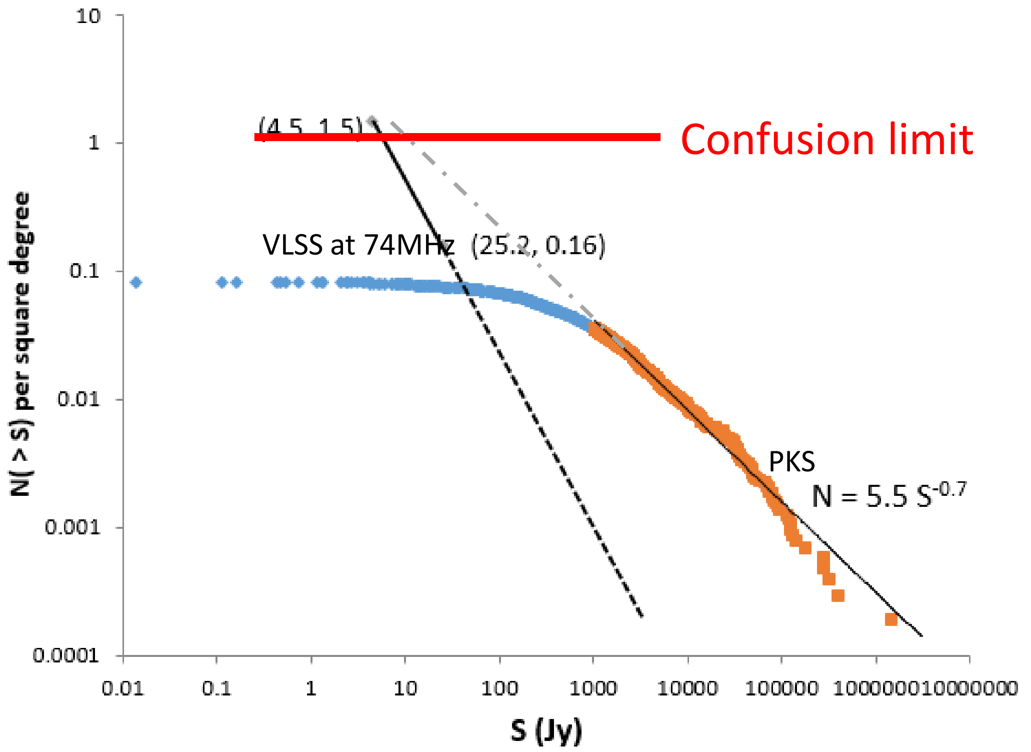
Cont'd

- For 10 MHz, confusion limits won't be reached in 2 years with 10 antennas (1 MHz BW)
- The confusion effect can only be reduced by observing with longer baselines.
- It's recommended to extend the longest baseline, even at the expense of reduced number of antennas.

Frequency	Resolution	Confusion Limit	Confusion Limit (Jester & Falcke)
0.1 MHz	103 arcmin	489Jy	1963Jy
1 MHz	10.3 arcmin	5.6Jy	11.3Jy
10 MHz	1 arcmin	65mJy	65mJy
		m=30	m=12.9
		Spectral index -0.4	Spectral index -0.7

1MHz Confusion limit

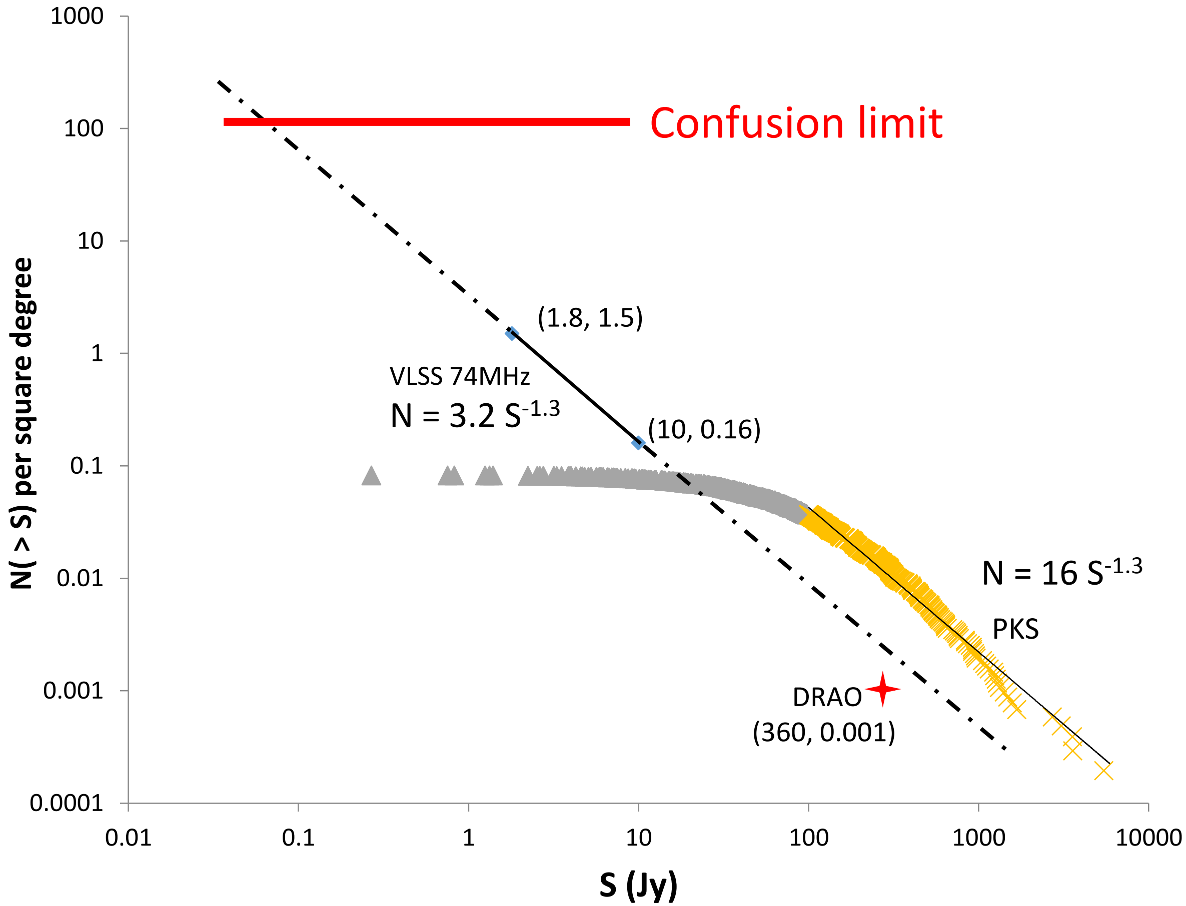
- For PKSCAT90, we have: $\sigma_c = 10\ Jy \quad (\mathrm{C} = 5.5, \beta = -0.7, \mathrm{m} = 30)$
- ~10^4 sources



- However the power law from linear fit (S>1000Jy) may not be valid for faint sources, which tend to be far and young galaxies, due to cosmological history of galaxy and star formation. Further study is needed to improve assumption of dN/dS at the faint end.

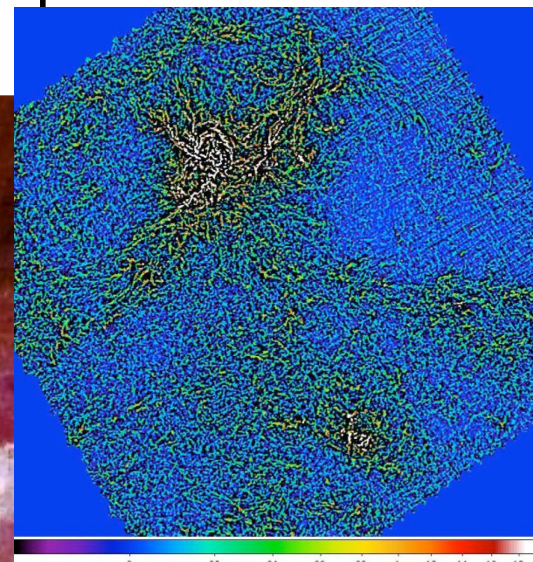
10MHz Confusion limit

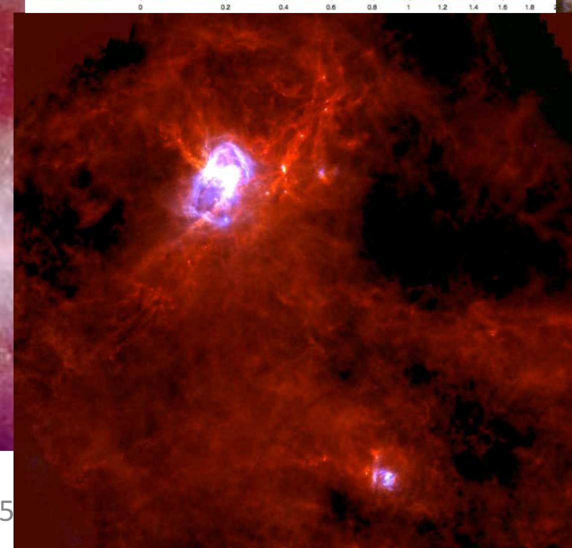
~10^6 sources

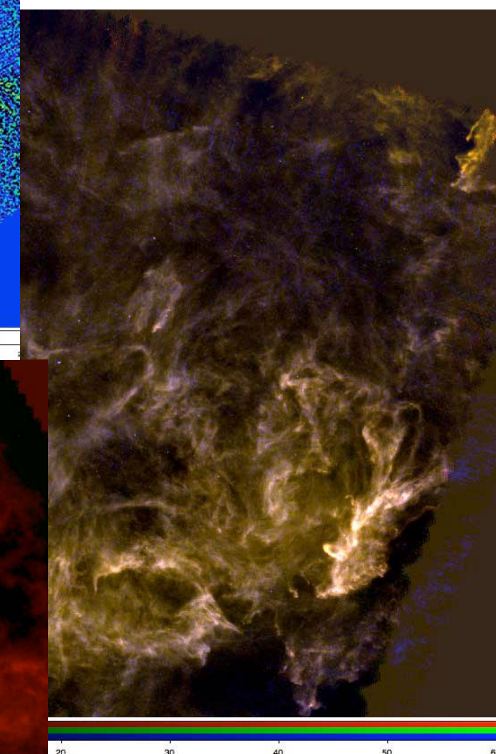


Then there are IPM / ISM scattering effects

- Are scattering / smearing effect sof ISM and IPM homogeneous in angular space and in time?







summary

- Extrapolation of VLA VLSS 74 MHz survey and Parkes PKSCAT90 catalog agree well in dN/dS slope at 10 MHz
- With a 100 km baseline
  - At 1 MHz 1.1 source / sq. deg can be resolved without confusion. The confusion limit and 5.6 Jy. A maximum of 10^4 sources can be detected.
  - At 10 MHz the limits are 110 source/ sq. deg and 0.065 Jy.
- There is not a lot of room to improve sensitivity to have more than three antennas at 1MHz.
- Extending the longest baseline significantly beyond 100 km is recommended.

thanks

Number of sources in *PKSCAT90* that can be detected with different survey parameters at *10MHz*

Number of antenna	**Bandwidth (MHz)**	**Sensitivity (Jy)**
2		3.5
3	1	2.0
10		0.5
2		1.1
3	10	0.6
10		0.2

In the calculations we assume that: 2 polarizations for each antenna, 90 days observation period , 1/3 duty cycle (observe only when shielded), and 1-bit sampling (36% sensitivity loss).