Detection of Diffuse Radio Emission in SPT Clusters

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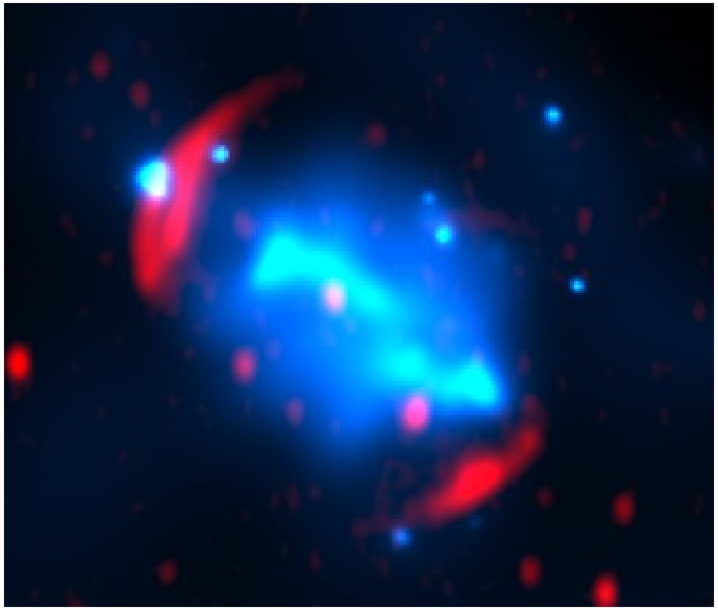
- The warm intracluster medium (ICM) contains 30-40% of the matter in the universe, also contains cosmic ray and protons which have been accelerated in magnetic fields over regions millions of light years across.

- The signature of the accelerated particles is diffuse radio emission seen in two forms: radio relics and radio halos.

Radio Relics

- Cluster outskirts (elongated, ~1 Mpc), Irregular morphology
- Radio emission traces merger shocks
- Particle acceleration mechanism:

  diffuse shock acceleration



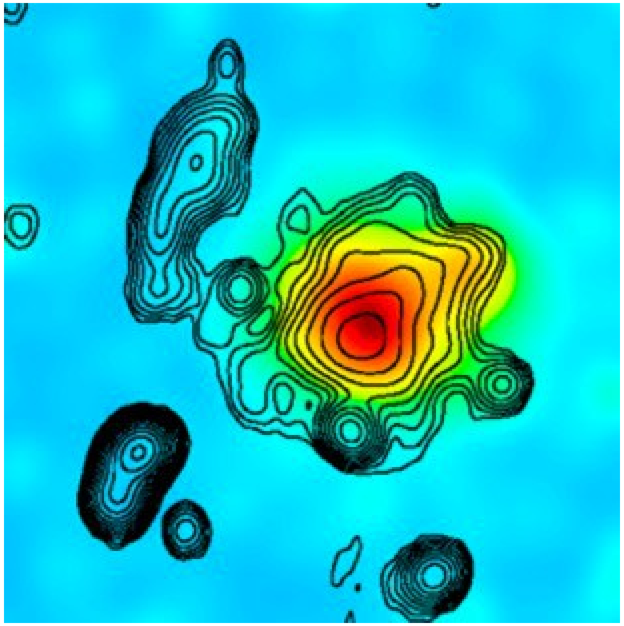
MACS J1752.0+4440 (van Weeren et al. 2012; Bonafede et al. 2012)

Radio halos:

- Smooth, centrally located, typical sizes of 1 Mpc
- low surface brightness and steep radio spectrum
- Particle acceleration mechanism:

Radio emission generated via turbulent re-acceleration mechanism

Radio emission from secondary electrons (products of hadronic collisions)

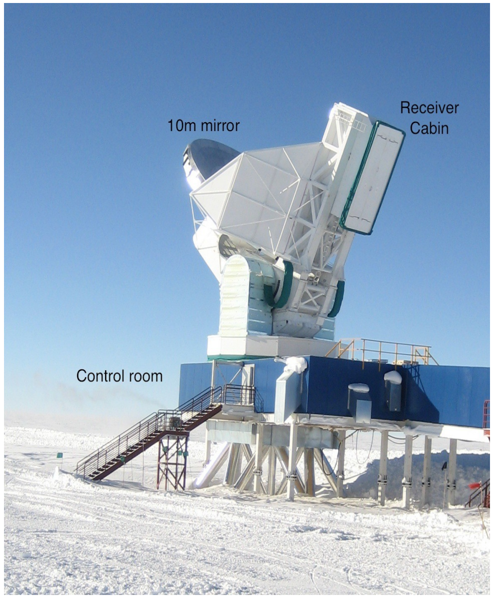


A2744 (Govoni et al. 2001; Feretti et al. 2012)

SPT Clusters

The ***S**outh **P**ole **T**elescope* is a 10 meter diameter telescope located at the Amundsen-Scott South Pole Station, Antarctica.

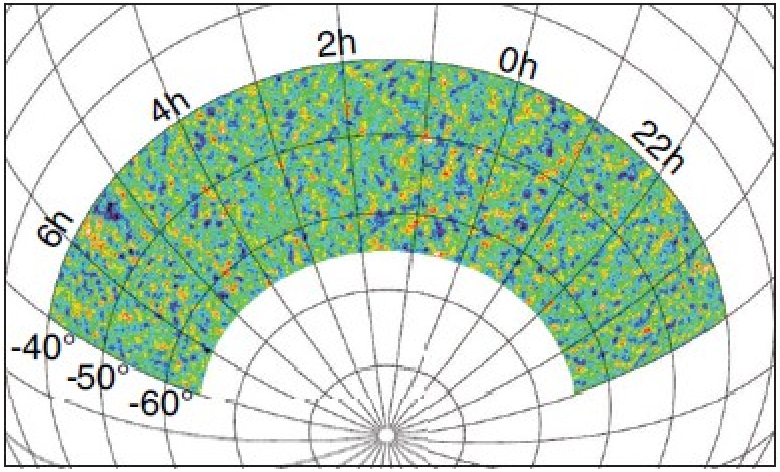
The high sensitivity and high angular resolution of the SPT enables several ambitious scientific programs. The initial observational program is a large survey for galaxy clusters detected by the Sunyaev-Zel'dovich Effect.



(www.phys.cwru.edu)

From 2008 to 2011 the telescope was used to conduct the SPT-SZ survey of ~ 2500 sq deg of the southern sky at **95**, **150** and **220** GHz. The survey covers a contiguous region from 20h to 7h in right ascension and -65 deg to -40 deg in declination.

Bleem et al. (2015) presented a catalog of galaxy clusters selected via their SZ effect signature from 2500 sq degrees of SPT data. A total of **677** cluster candidates are identified above a signal-to-noise threshold of 4.5. Of the confirmed Clusters, **415** were first identified in SPT data.

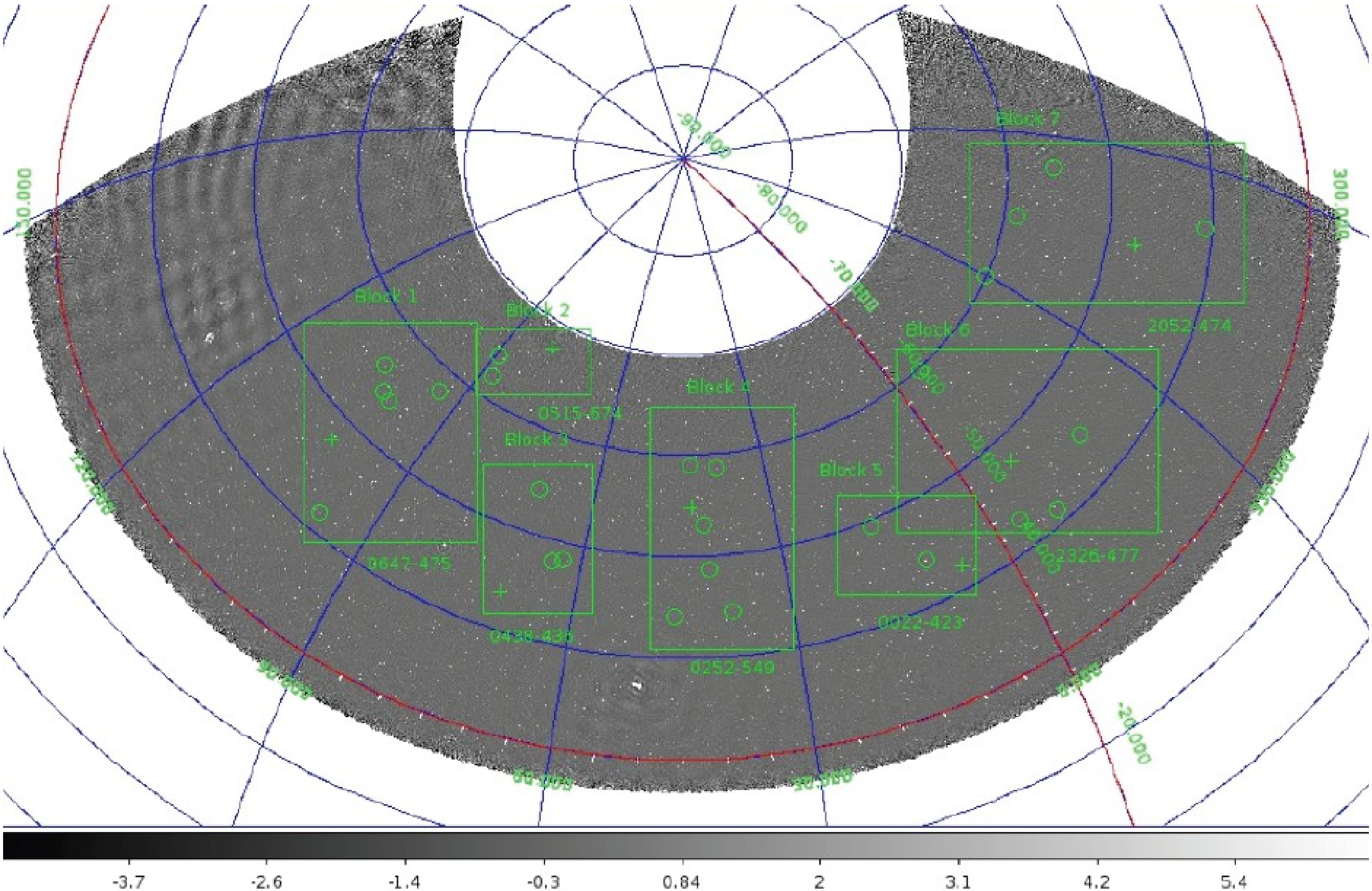


2500 sq deg SPT-SZ survey (Story et al. 2013)

SPT Clusters with the MWA

We have examined all 224 SPT clusters with the MWA using commissioning data (MWACS). We find 24 clear detections of diffuse emission, including previously known relics and halos. However, the resolution and sensitivity of the commissioning data is poor compared to the full MWA.

26 of the most massive SPT clusters have also been followed up with the ATCA (PI Johnston-Hollitt) and the full MWA. We present two of these here.



(Luke Hindson)

SPT CL 2023-5535:

z=0.2320

(20h 23m 24.5s, -55d 35m 32s)

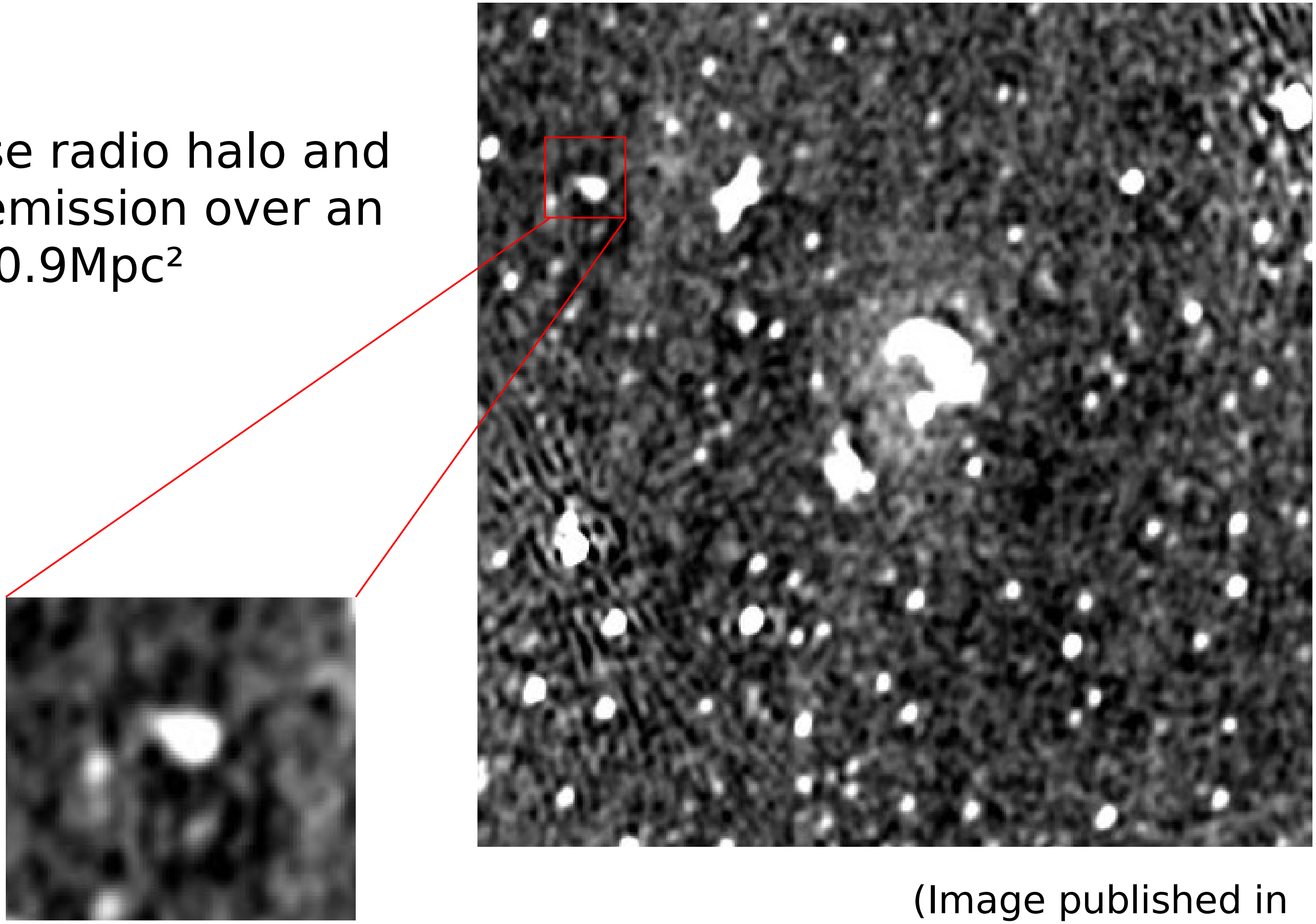
SPT CL 2201-5956 (Abell 3827):

z=0.098

(22h 01m 53.3s, -59d 56m43.4s)

CL 2023-5535

- z=0.2320
- The diffuse radio halo and the relic emission over an extent ~ 0.9Mpc²



(Image published in Hindson et al. 2014)

MWA: 120MHz, 149MHz, 180MHz, 226MHz

Published in Hindson et al. 2014

SUMSS: 843MHz

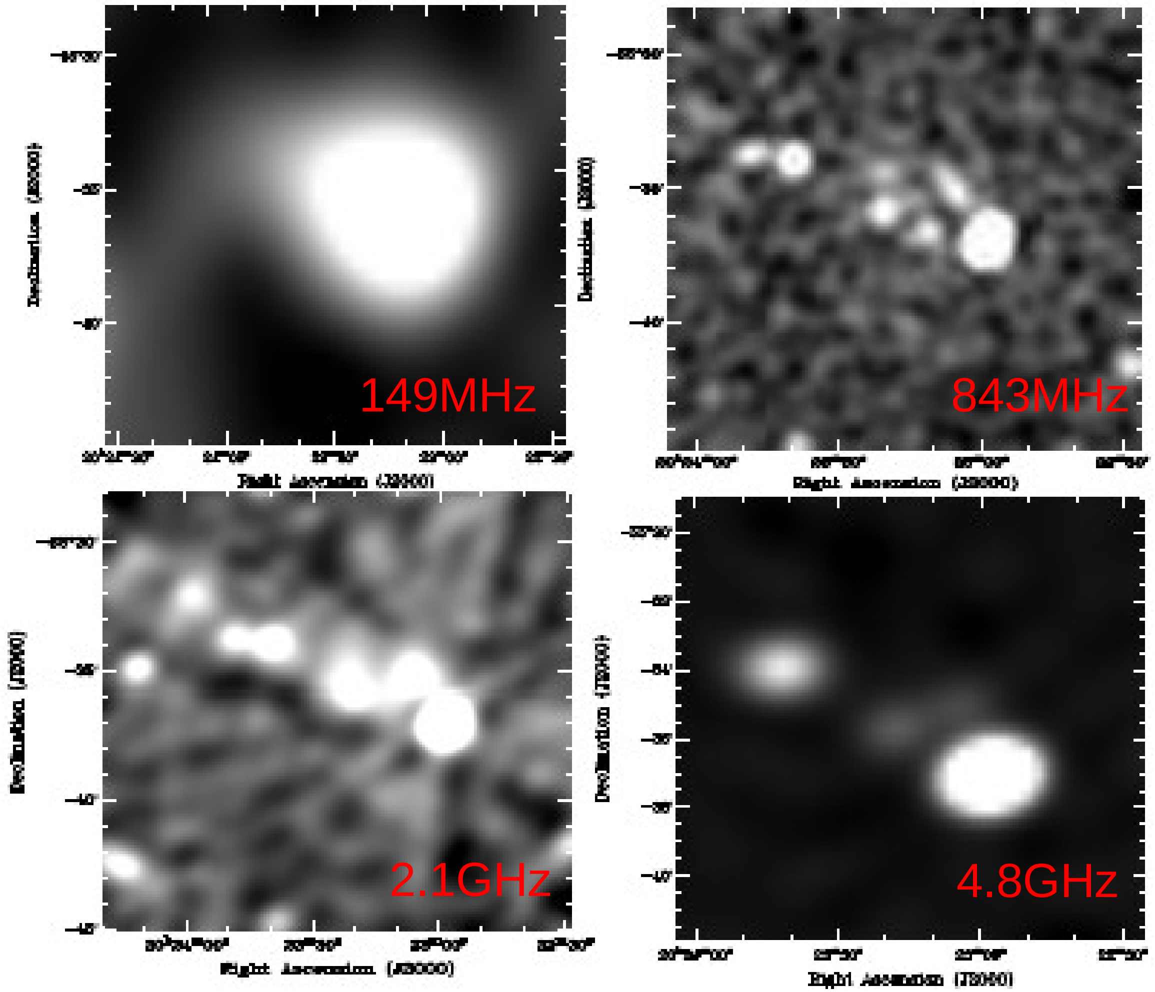
ATCA:

2.1GHz 1382MHz, 1868MHz, 2358MHz, 2814MHz

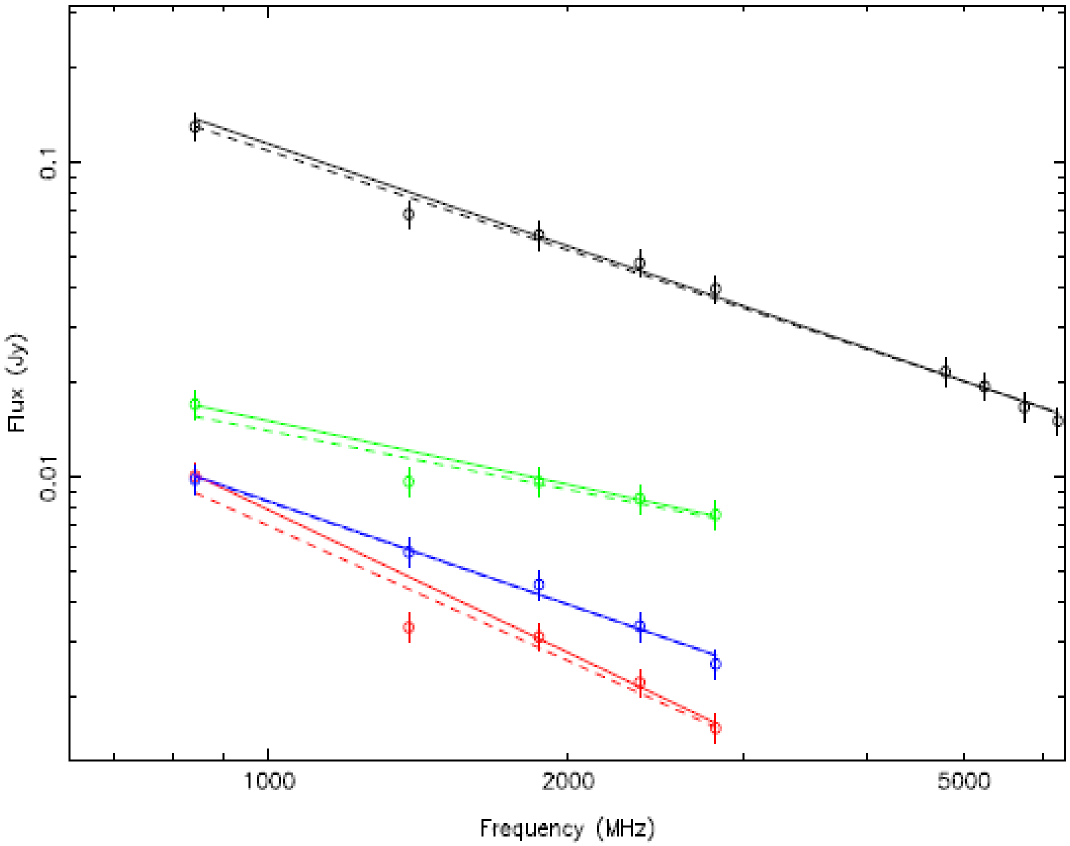
SPT project, PI Johnston-Hollitt

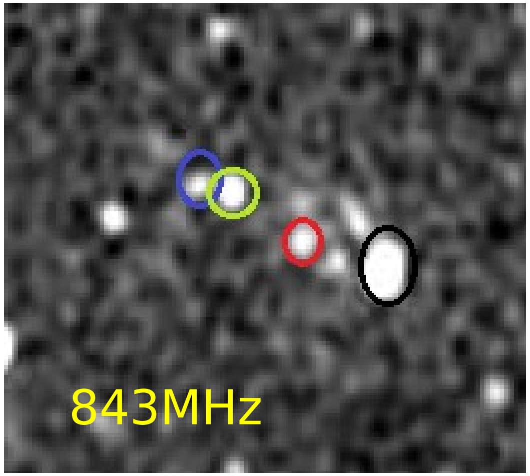
4.8GHz 4783MHz, 5241MHz, 5745MHz, 6212MHz

Srinivasan MSc Thesis


149MHz
843MHz
2.1GHz
4.8GHz

Subtraction of the radio sources:





α= $-1.08^{+0.03}_{-0.03}$

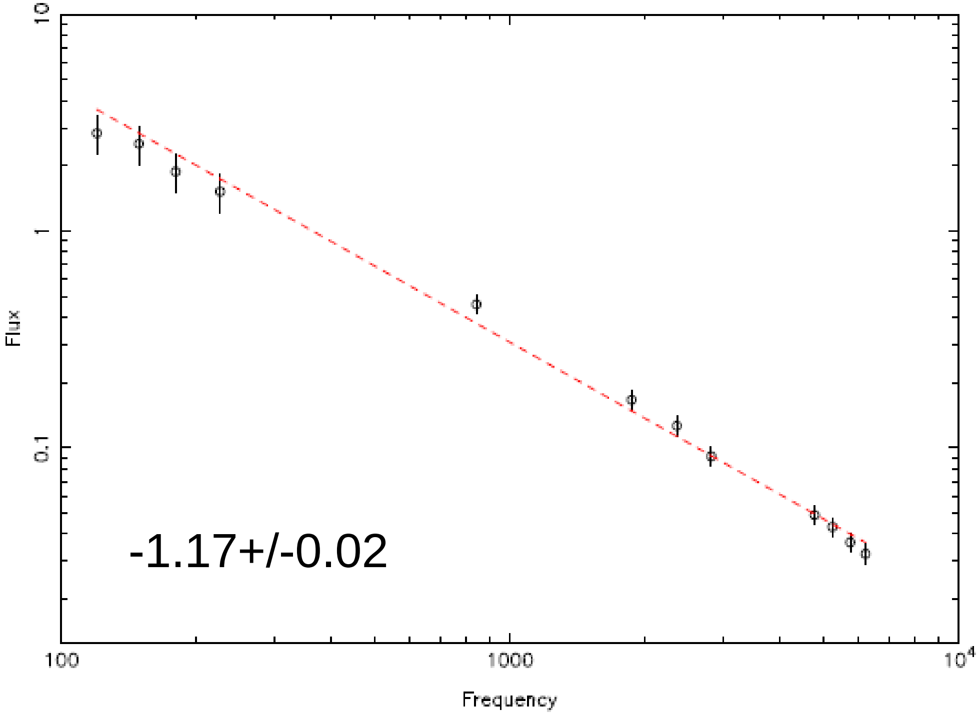
α= $-1.51^{+0.07}_{-0.06}$

α= $-0.67^{+0.06}_{-0.07}$

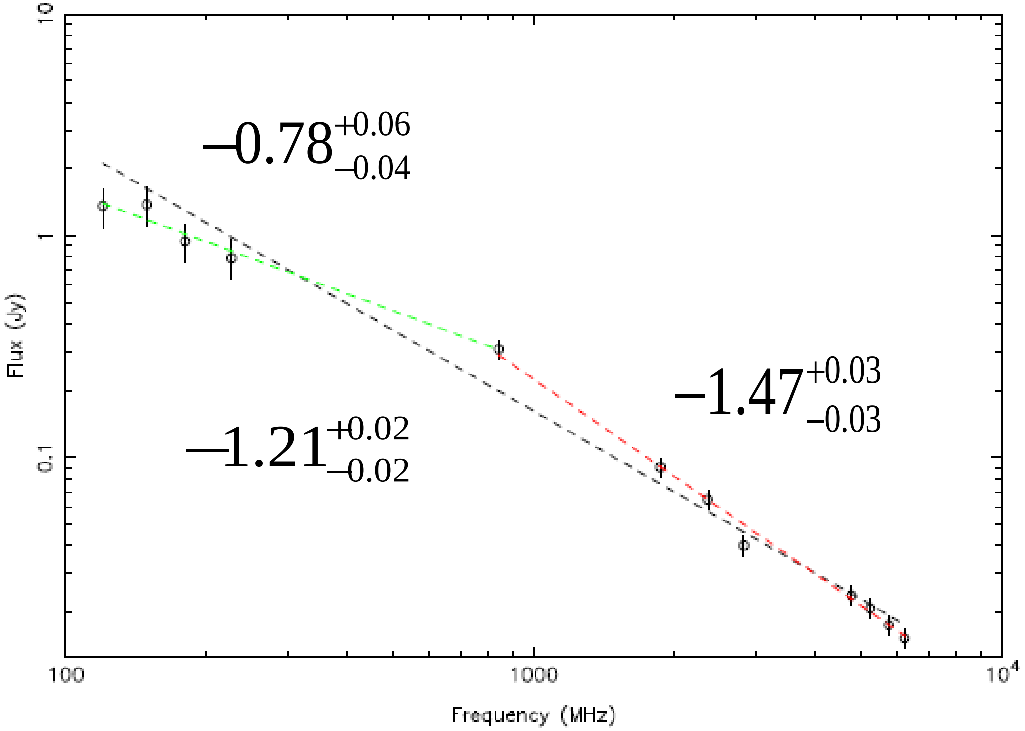
α= $-1.09^{+0.06}_{-0.06}$

- A partial subtraction of the radio relic and radio halo
- Incorrect subtraction of the discrete sources
- Different weighting schemes are used in the MWA and ATCA data reductions
- Flux scaling ?

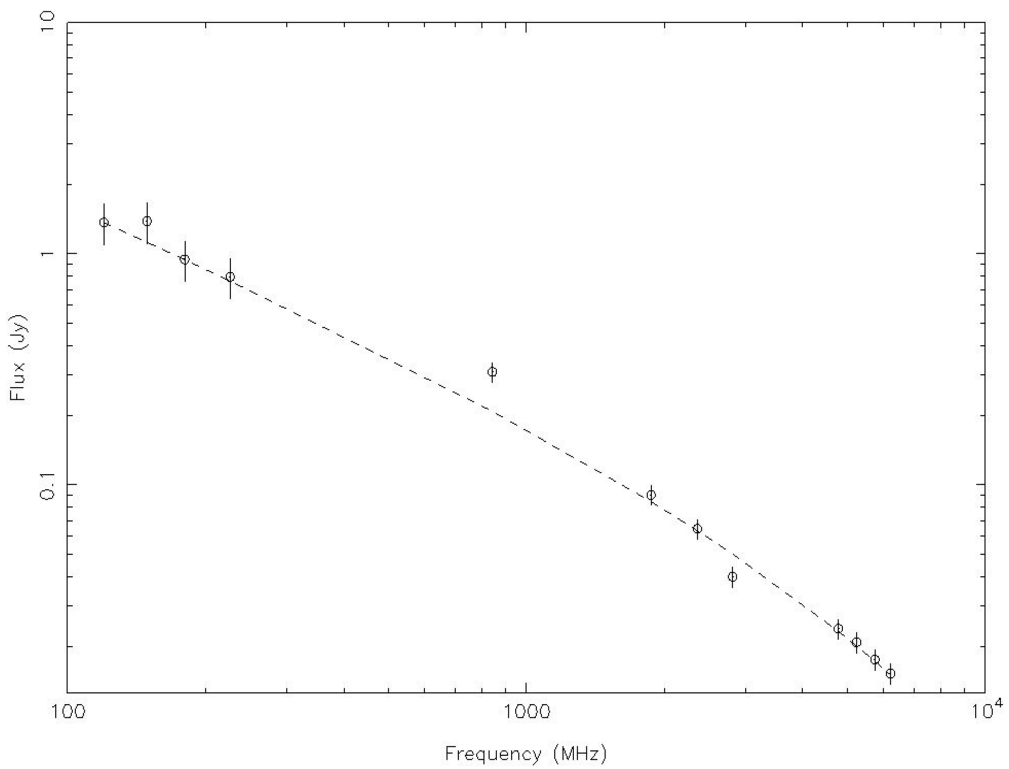
Point sources + diffuse emission :



After the subtraction of discrete sources:



Radio Relic –
Reviving fossil radio plasma in clusters of galaxies by adiabatic compression in environmental shock waves (Enßlin & Gopal-Krishna, 2001)



The spectral index of the resulting electron spectrum from an initial power law distribution is fitted as **a=2.67**. The maximal electron momentum is related to the magnetic field strength of the cluster diffuse component.

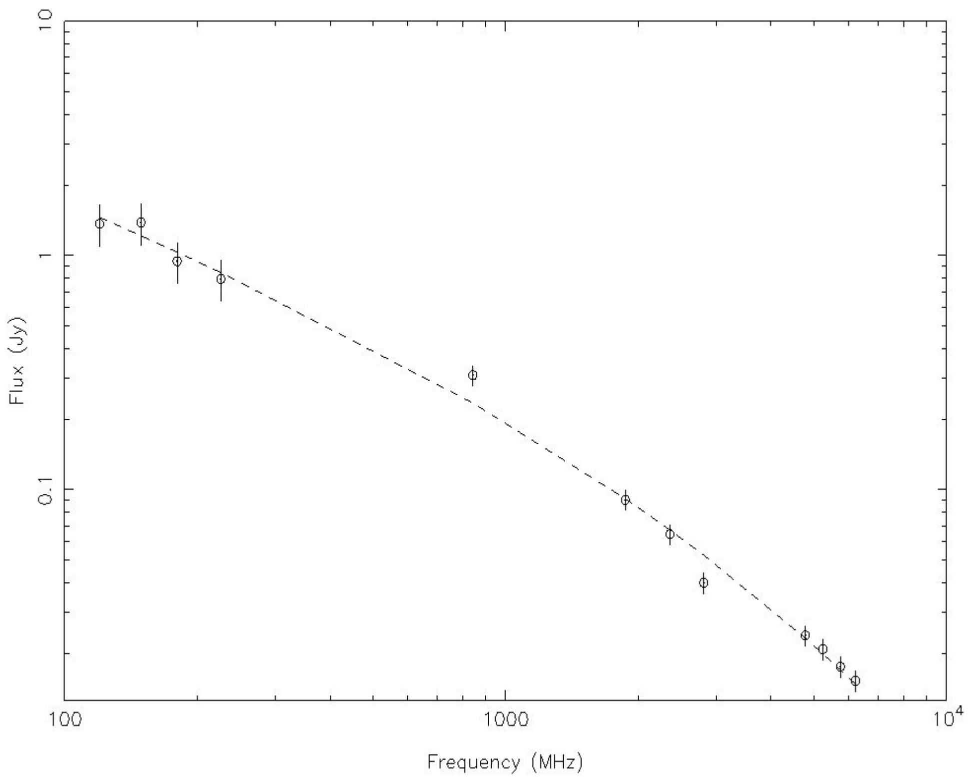
If the magnetic field strength of the cluster is assumed to be ~ 1uG, then the fitted maximal electron momentum in this case is **10^5**.

Radio Halo - In-situ acceleration model
The diffuse radio emission from the Coma cluster
Shlickeiser et al. (1987)

Parameter constraints in the in-situ acceleration model *(when we neglect shock wave acceleration corrected for bremsstrahlung and adiabatic deceleration losses with respect to resonant momentum diffuse acceleration)* :

Cutoff frequency: **0.04-0.72 GHz**
Fitted: **1.23+/-0.3 GHz**

Gamma: **4.34 +/- 0.13**
(spectral index=(Gamma-3)/2)



The diffuse radio emission over an extent ~ $0.9 Mpc^2$

We obtain a steep spectral index of the diffuse emission:

-1.21 (with MWA data) and
-1.47 (without MWA data)

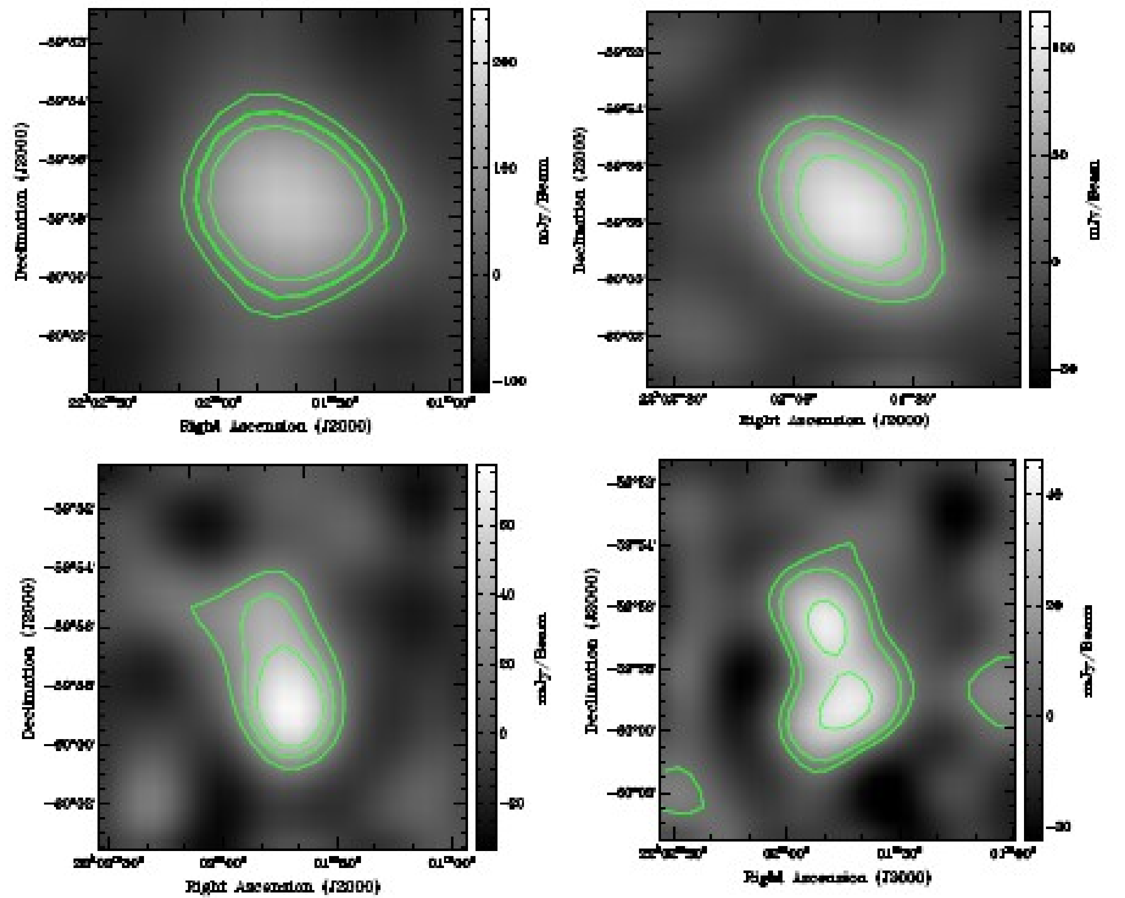
The MWA data allows us to see the spectral curvature.

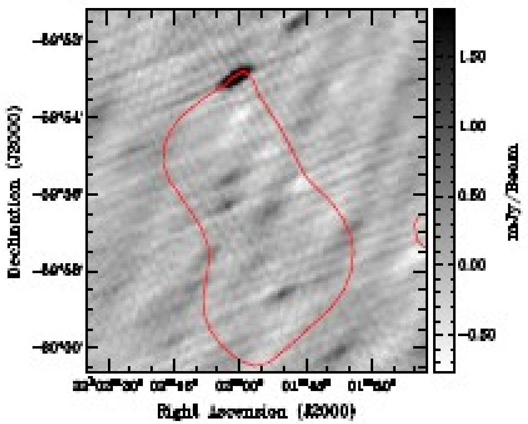
CL 2201-5956

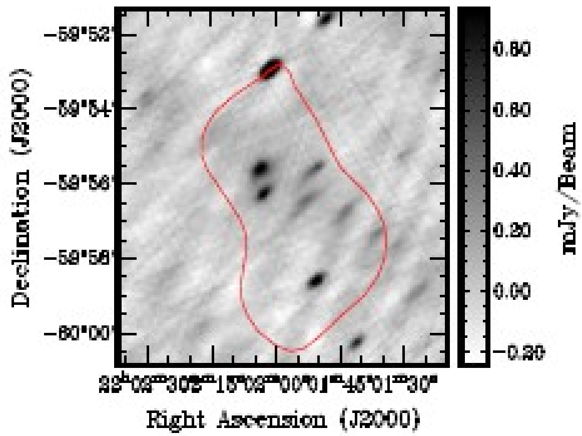
z=0.098

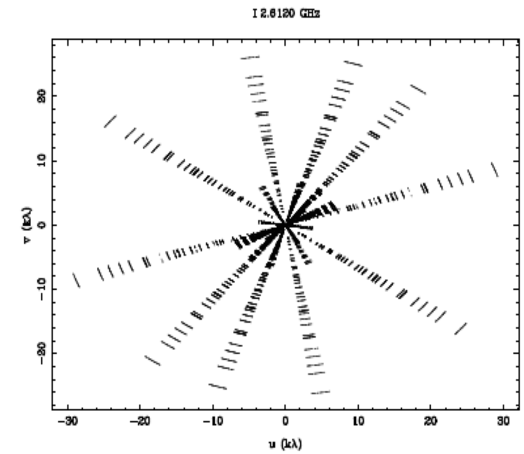
diffuse radio emission over an extent ~ 0.87Mpc

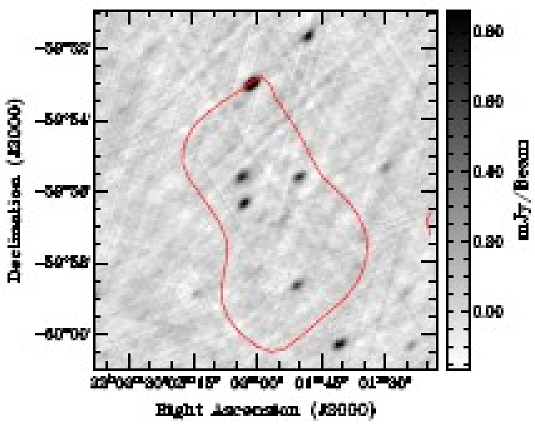
ν_c (MHz)	RMS noise (Jy/beam)	beam (arcsec)
120	0.059	269.3×269.3
150	0.028	194.8×194.8
180	0.010	146.9×146.9
215	0.008	126.0×126.0

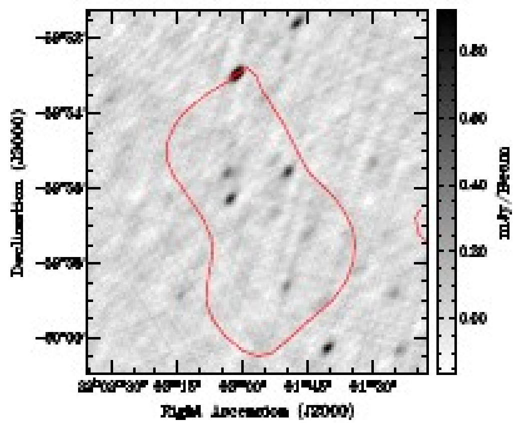








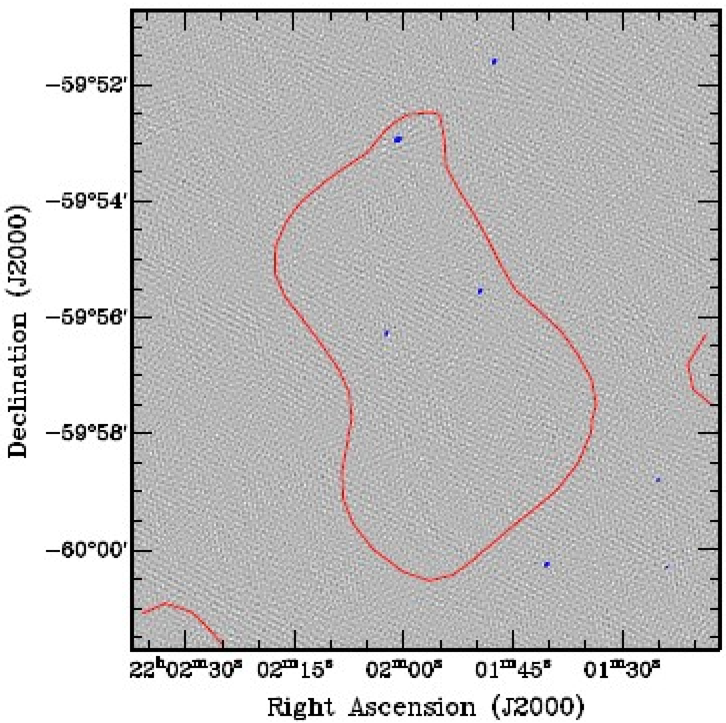




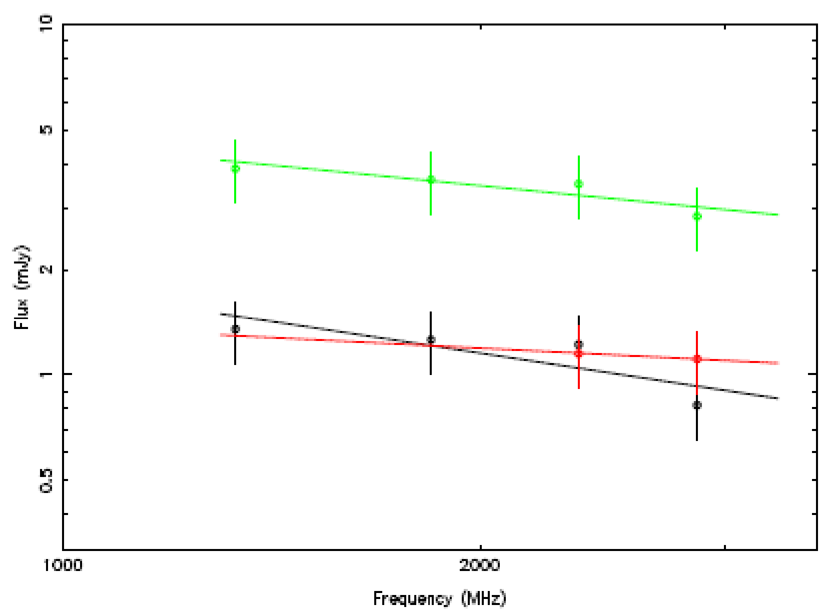
ATCA:
1382MHz, 1868MHz,
2358MHz, 2814MHz

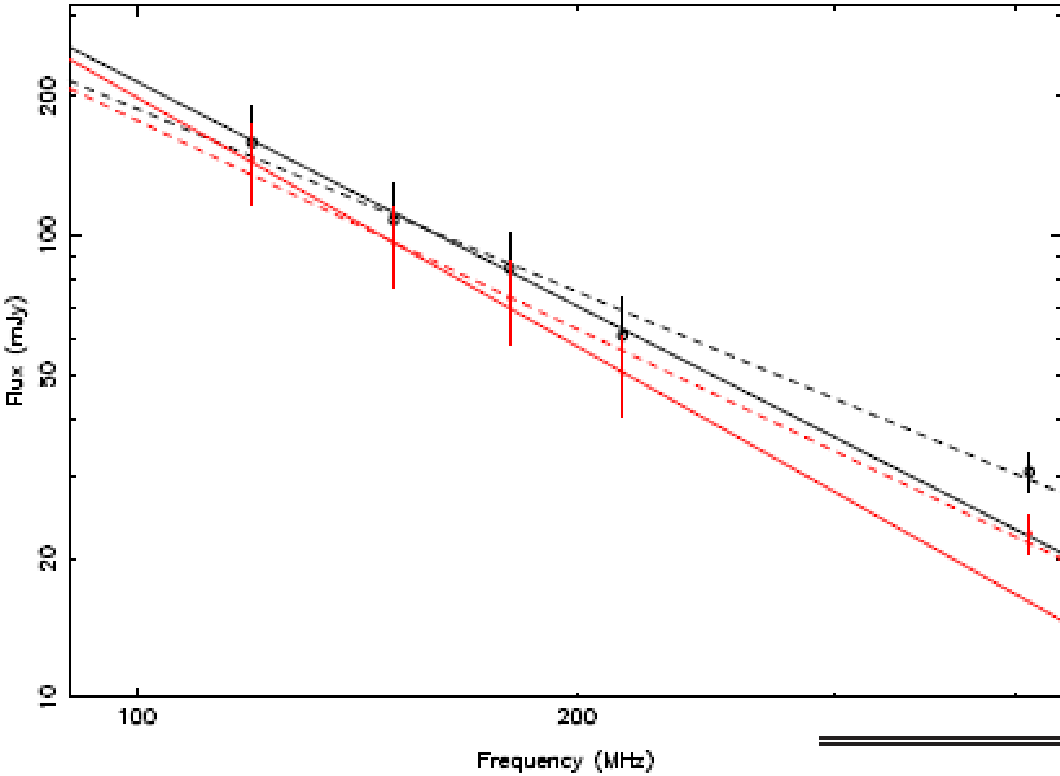
Configuration	Date	t_{scan} (mins)	Bandwidth (MHz)	ν_c (MHz)
750D	09,10,13-08-2013	355.2	2048	2100
6A	20,21,22-07-2013	195	2048	2100
EW352	19,20,21-06-2013	224	2048	2100

ν_c (MHz)	RMS noise (mJy/beam)	beam (arcsec)	pa (degrees)
1332	0.117	38.00×14.99	-59.74
1844	0.050	25.98×14.12	-51.98
2356	0.029	18.15×10.54	-50.56
2868	0.048	17.60×10.38	-48.25



source	1	2	3
RA	22 02 01.95	22 01 49.33	22 02 00.61
DEC	-59 56 18.41	-59 55 34.69	-59 52 53.43
S_{1332}	1.34	-	3.88
S_{1844}	1.26	-	3.61
S_{2356}	1.22	1.15	3.51
S_{2868}	0.82	1.11	2.84
α	0.60	0.20	0.39





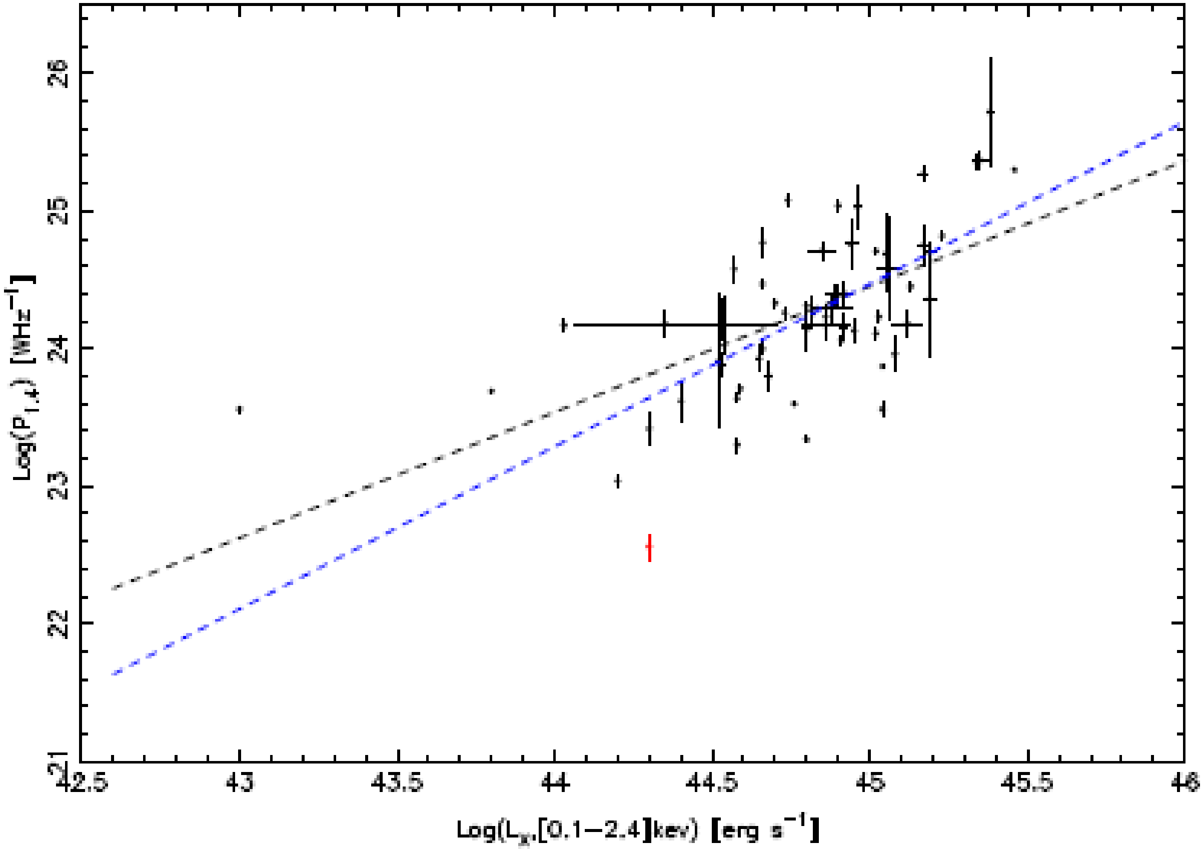
	S_0	α
MWA data points:		
diffuse emission+discrete sources	5.56 ± 0.60	1.61 ± 0.27
diffuse emission only	5.89 ± 0.60	1.79 ± 0.27
MWA & 408MHz Molonglo data points:		
diffuse emission+discrete sources	4.91 ± 0.23	1.32 ± 0.09
diffuse emission only	5.25 ± 0.23	1.50 ± 0.10

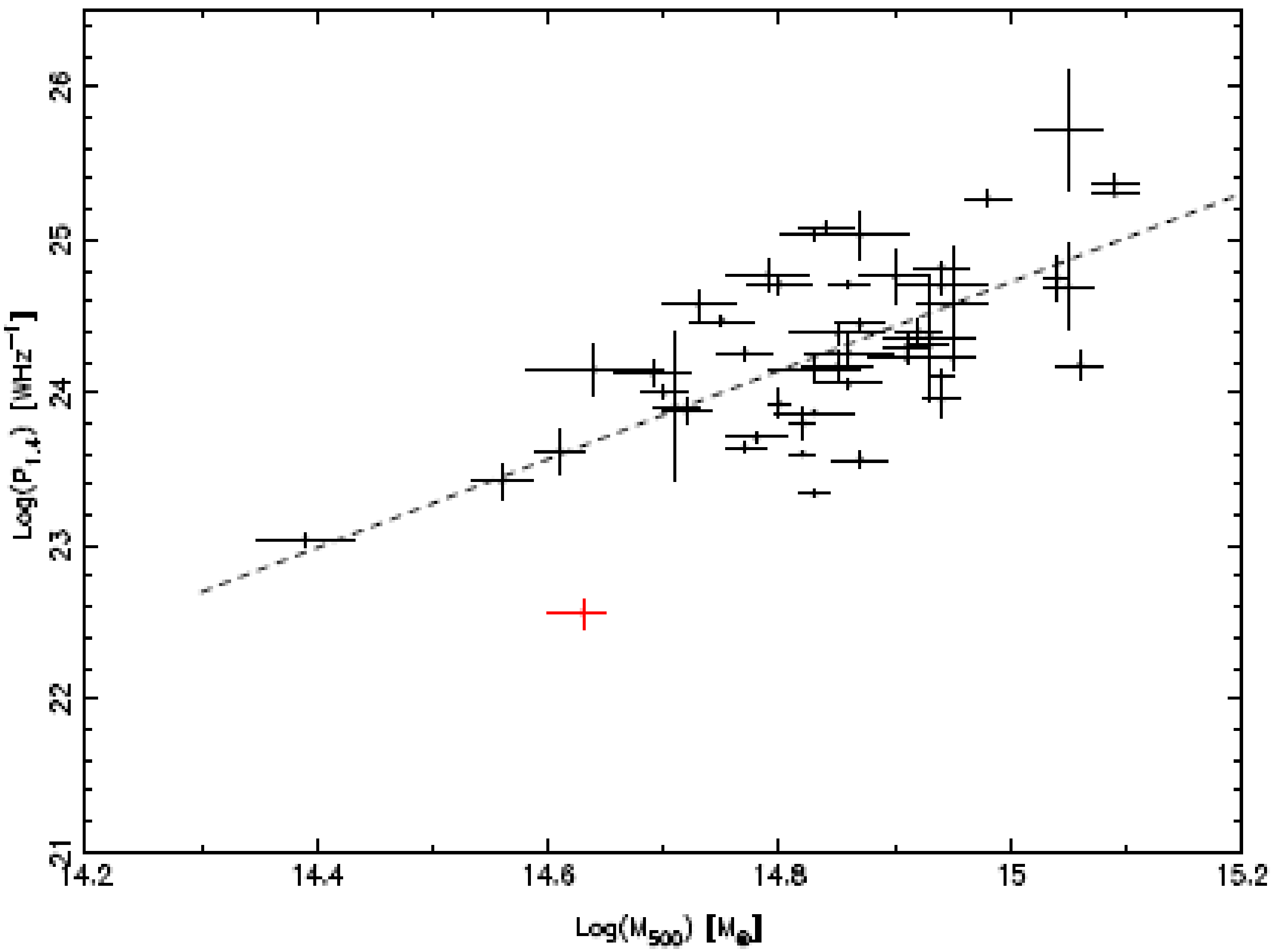
Table 5. Fitting parameters of the spectra of diffuse emission : $\log F = S_0 + (-\alpha)\log\nu$.

Cluster radio halo ?

$P_{1.4} = 3.59 \times 10^{22}$ Watt Hz^{-1}

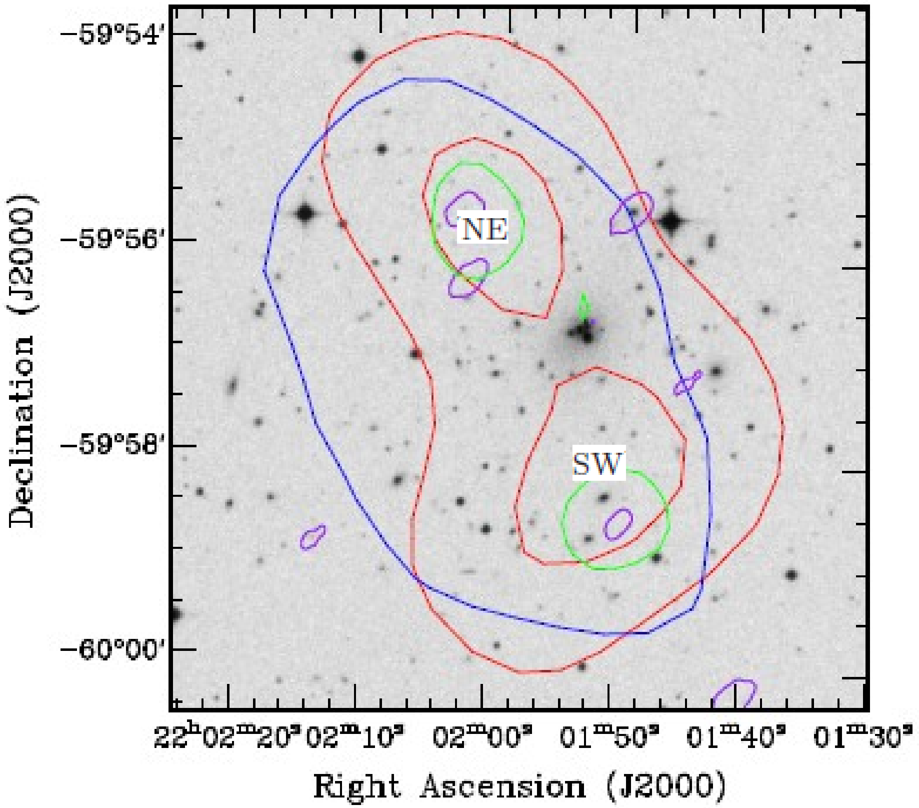
$L_X(0.1-2.4keV) = 2.1 \times 10^{44} ergs^{-1}$





26
25
24
23
22
21
Log(P1.4) [WHz−1]
14.2
14.4
14.6
14.8
15
15.2
Log(M500) [M⊙]

Twin relics ?



NE 239.29 h^{-1}kpc

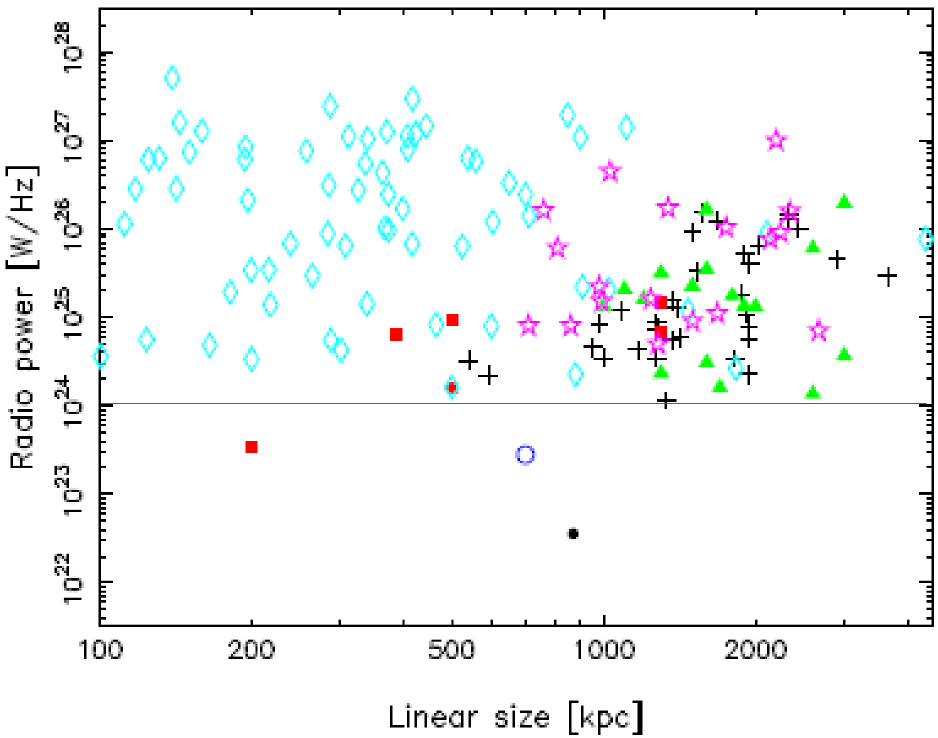
>1.75 mJy at 1844MHz

SW 193.39 h^{-1}kpc

>1.19 mJy at 1844 MHz

170-231 MHz (MWA)
843 MHz (SUMSS)
408 MHz (Molonglo)
2868 MHz (ATCA)

Dying radio galaxy ?



The 1.4 GHz radio power against linear size P-D diagram for GRGs in the literature.

- FR-I and FR-II objects compiled by Laing et al. (1983) with z < 0.6
- GRGs measured by Saripallie et al. (2005)
- GRGs measured by Schoenmakers et al. (2001)
- GRGs discovered before 1998
- 6 disc galaxies hosting large radio lobes, whose properties are listed in Table 5 in Hurley-Walker et al. (2015)
- Radio lobes of NGC1534 given in Hurley-Walker et al. (2015)
- SPT CL J2201-5956

THE ORIGIN OF DIFFUSE EMISSION

Emission Feature	**Cluster Radio Halo**	**Twin Relics**	**Dying Radio Galaxy**
LLS	*true*	*true*	*true*
Polarisation	*true*	*false*	-
Lack of core	*false*	*false*	*true*
Lack of optical ID	*false*	*false*	*true*

Summary

- Diffuse emission detected in two SPT clusters : **SPT CL J2023-5535** and **SPT CL J2201-5956**
  SPT CL J2023-5535 (*a radio halo*)
  SPT CL J2201-5956 (*a dying radio galaxy*)

- MWA observation is very important for our study since it covers very low frequency bands, but higher resolution is required.

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Thanks!