Polarization Surveys

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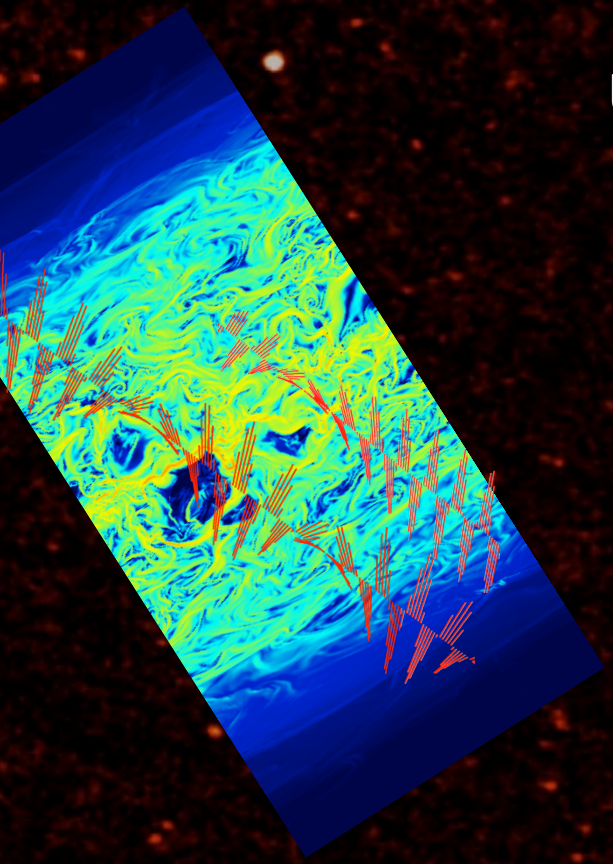
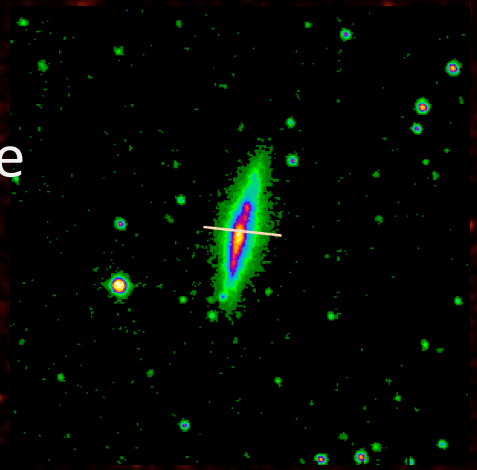
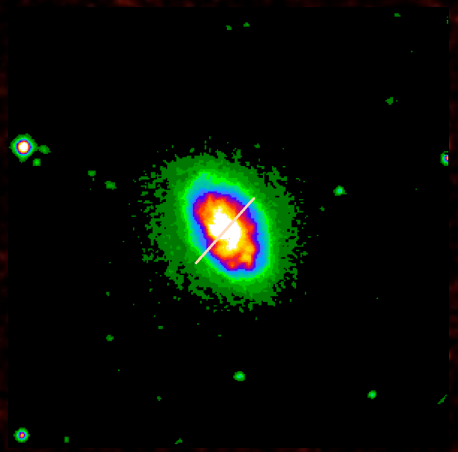
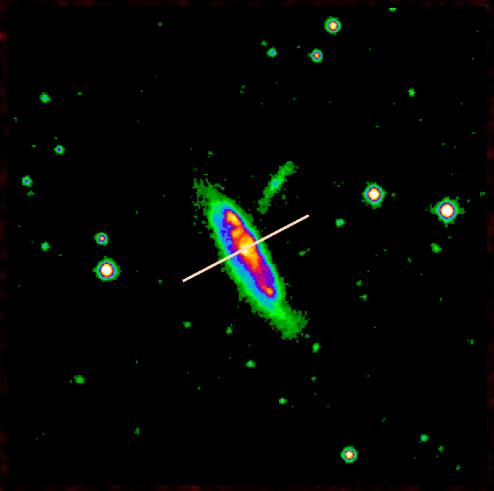








Core questions addressed by Polarization Surveys

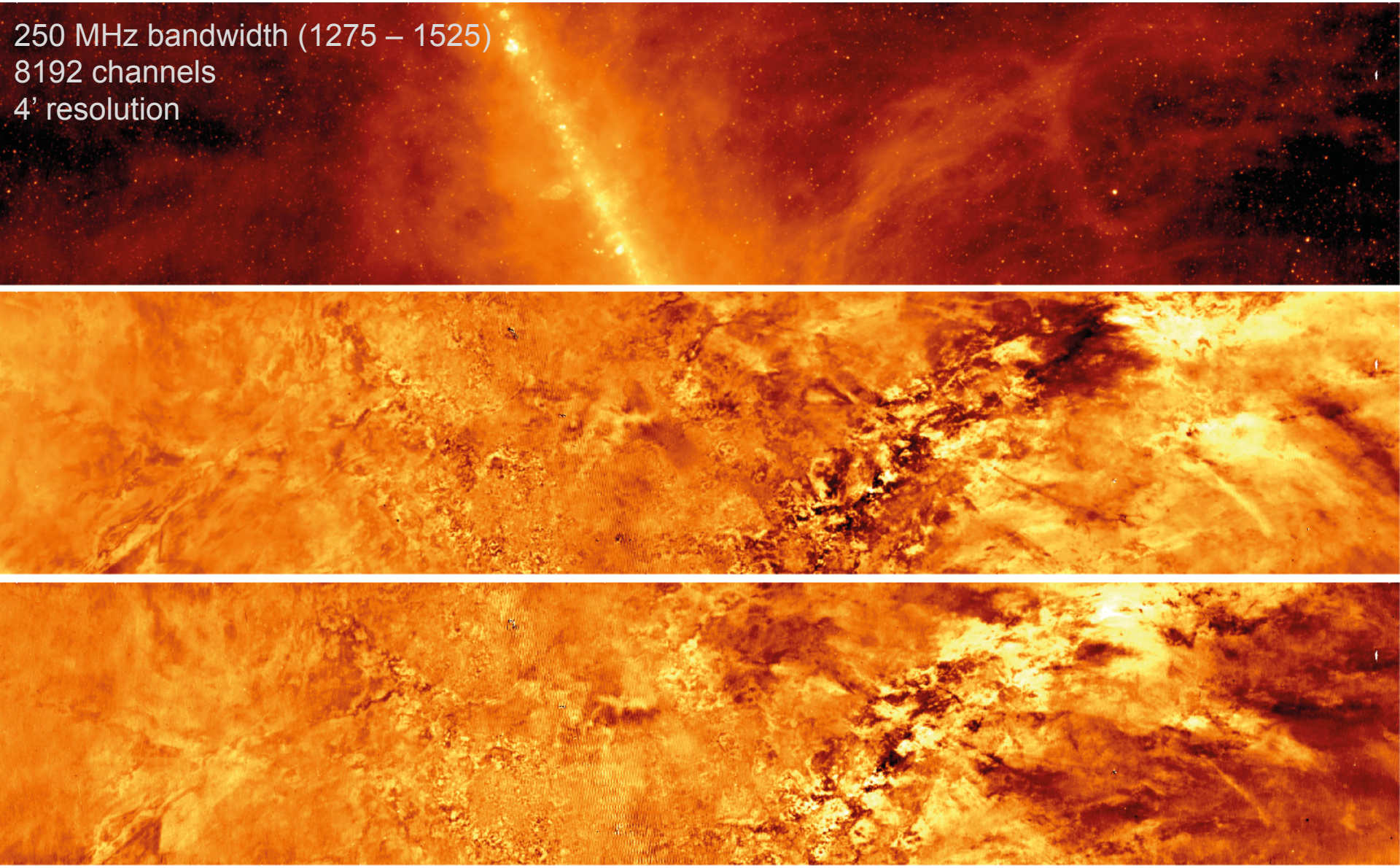
- Magnetism and galaxy evolution
  - When and how did coherent magnetic fields emerge in galaxies?
  - What is their relationship to and role in the (regulation of?) star formation history of the universe?
  - Role in global energetics and interactions with intergalactic environment
- Detection and characterization of the magnetic cosmic web
  - Can it be detected?
  - How did cosmic-scale fields arise?
  - What are its properties and how does it relate to large scale structure of matter?
- Magnetic Evolution of AGN over cosmic time
  - Relation to cosmic history of star formation, black hole evolution, environment,
  - What is the flux density fractional polarization relationship telling us?

Deep imaging of μJy polarized radio sources will be key

Pre-SKA Wide-area GHz Radio Polarization surveys Current and planned

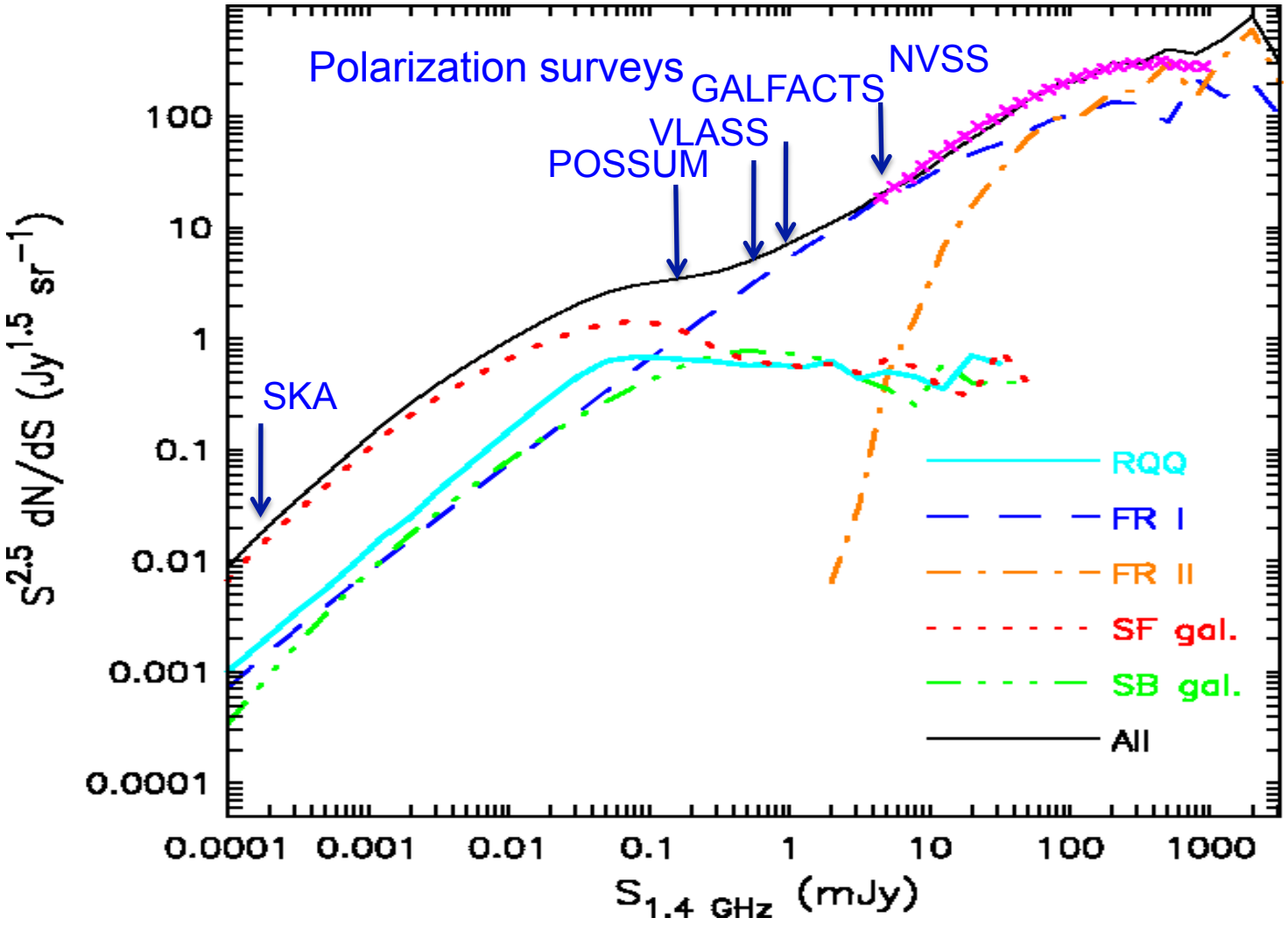
Telescope	Project	Sensitivity (1 σ)	Sky coverage (sq deg)	completion
VLA	NVSS	300 μJy	33,000	1998
Arecibo	GALFACTS	90 μJy	12,700	2015
ASKAP-12	Wide-cont	40 μJy	1,000	2017
ASKAP	POSSUM	10 μJy	33,000	2018
VLA	VLASS	68 μJy	33,000	2019

GALFACTS: I, Q, U



Radio Source Populations

Weakest source with detectable polarization (10σ)



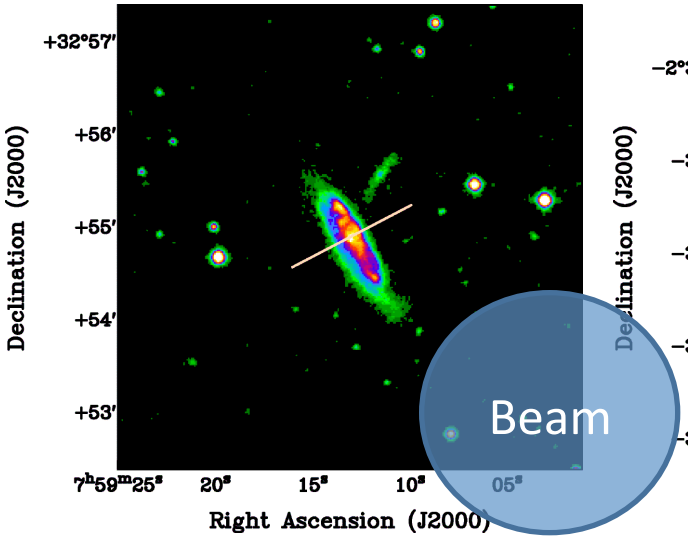
Pre-SKA Deep GHz Radio Polarization Surveys

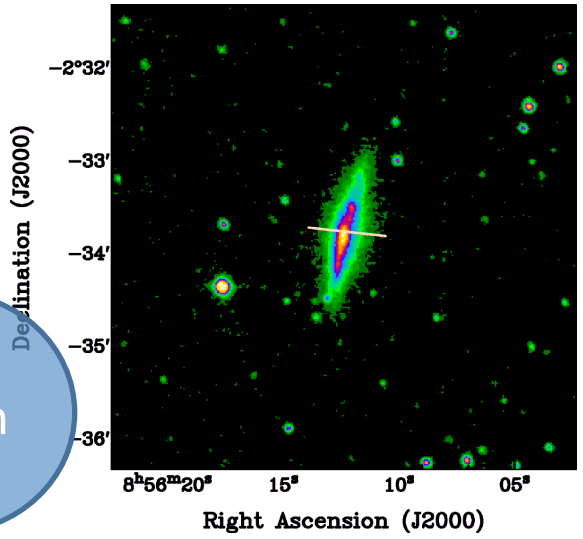
Telescope	Project	Sensitivity (1 σ)	Sky coverage (sq deg)	Resolution	Completion
GMRT	EN-1 uDPF	3 μJy*	1.2	5”	2013
VLA	EN-1 uDPF	1.5 μJy*	0.3	2”	2015
GMRT	SERVS Deep	2 μJy*	10	5”	2018
MeerKAT	MIGHTEE	1 μJy	(35)	8”	2018
MeerKAT	LADUMA	0.1 uJy	1	8”	2018
VLA	VDCS	1.5 uJy	10	1”	2019?

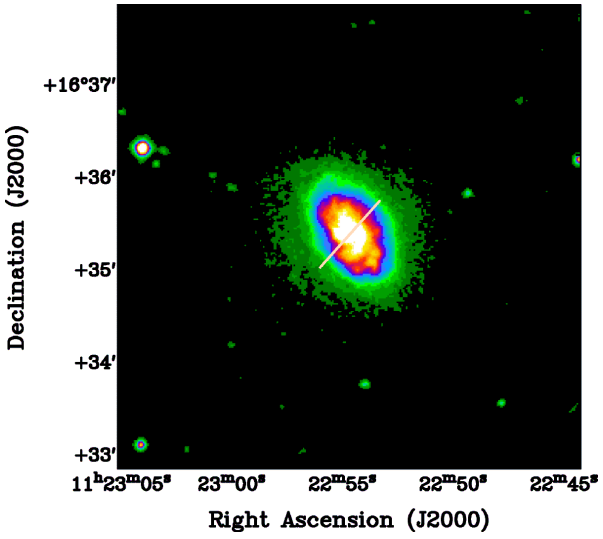
* Equivalent 1.4 GHz based on average spectral index of -0.8
Note that deep polarization also means deep total intensity

Effelsberg polarisation survey of disk local galaxies

Stil, Krause, Mitchell, Beck & Taylor (2009)







UGC 4132

V_{hel} = 5219 km s^{-1}

distance = 74 Mpc

V_{rot} = 257 km s^{-1}

UGC 4680

V_{hel} = 1631 km s^{-1}

distance = 27 Mpc

V_{rot} = --- km s^{-1}

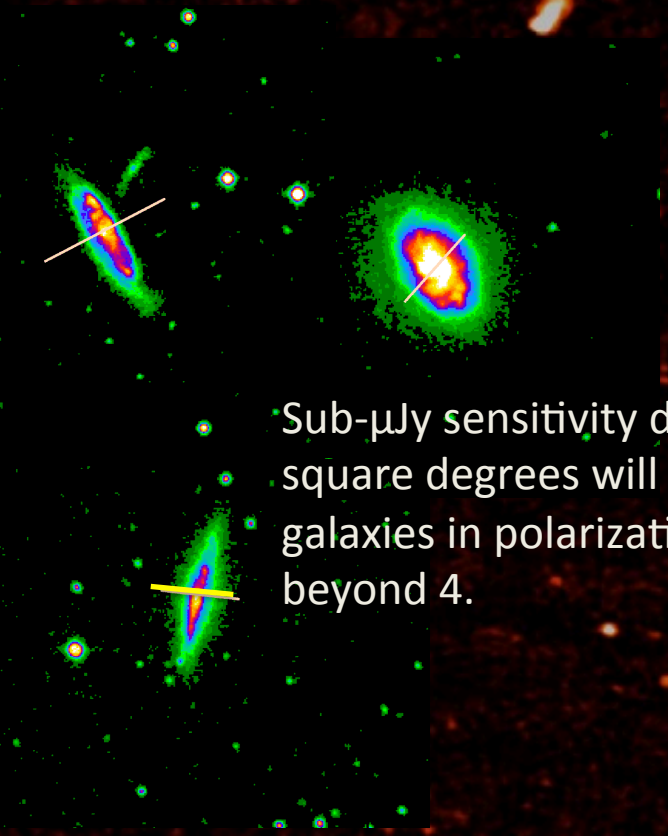
UGC 6936

V_{hel} = 1473 km s^{-1}

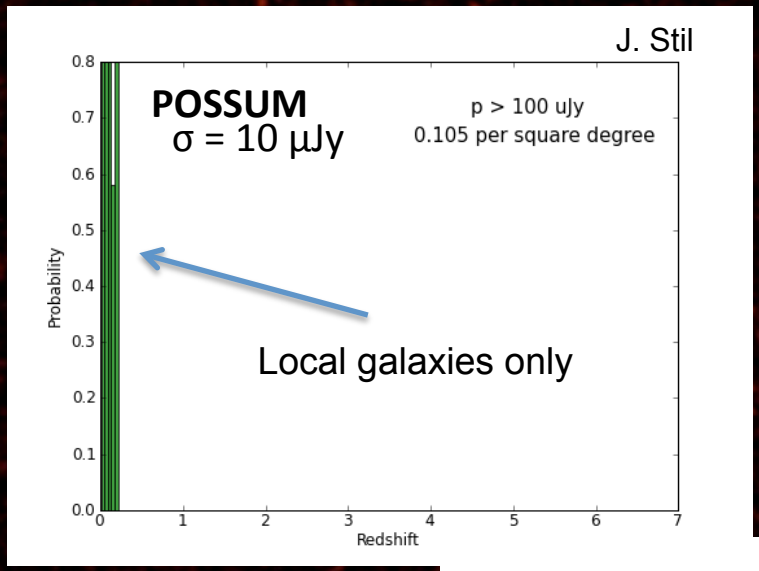
distance = 18 Mpc

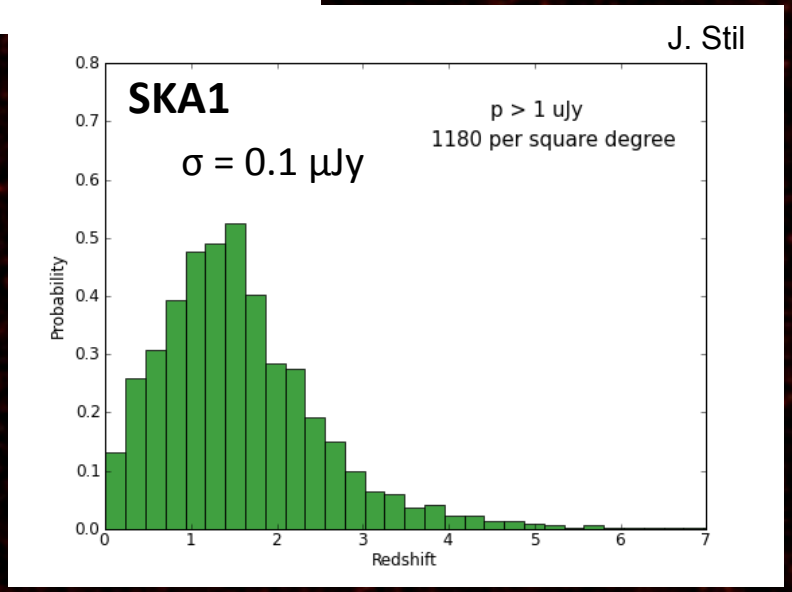
V_{rot} = 198 km s^{-1}

Magnetism and Galaxy Evolution



Sub-μJy sensitivity deep fields over several square degrees will detect thousands of galaxies in polarization out to redshifts beyond 4.





GMRT/JVLA Deep Polarization Fields

Largest dish arrays in the world upgraded with wide-band correlators (SKA1 Full-Stokes Deep Field Pathfinders)

GMRT software correlator

- 230 hours of observing 2011/12
  - 0.61 GHz
  - 32 MHz bandwidth

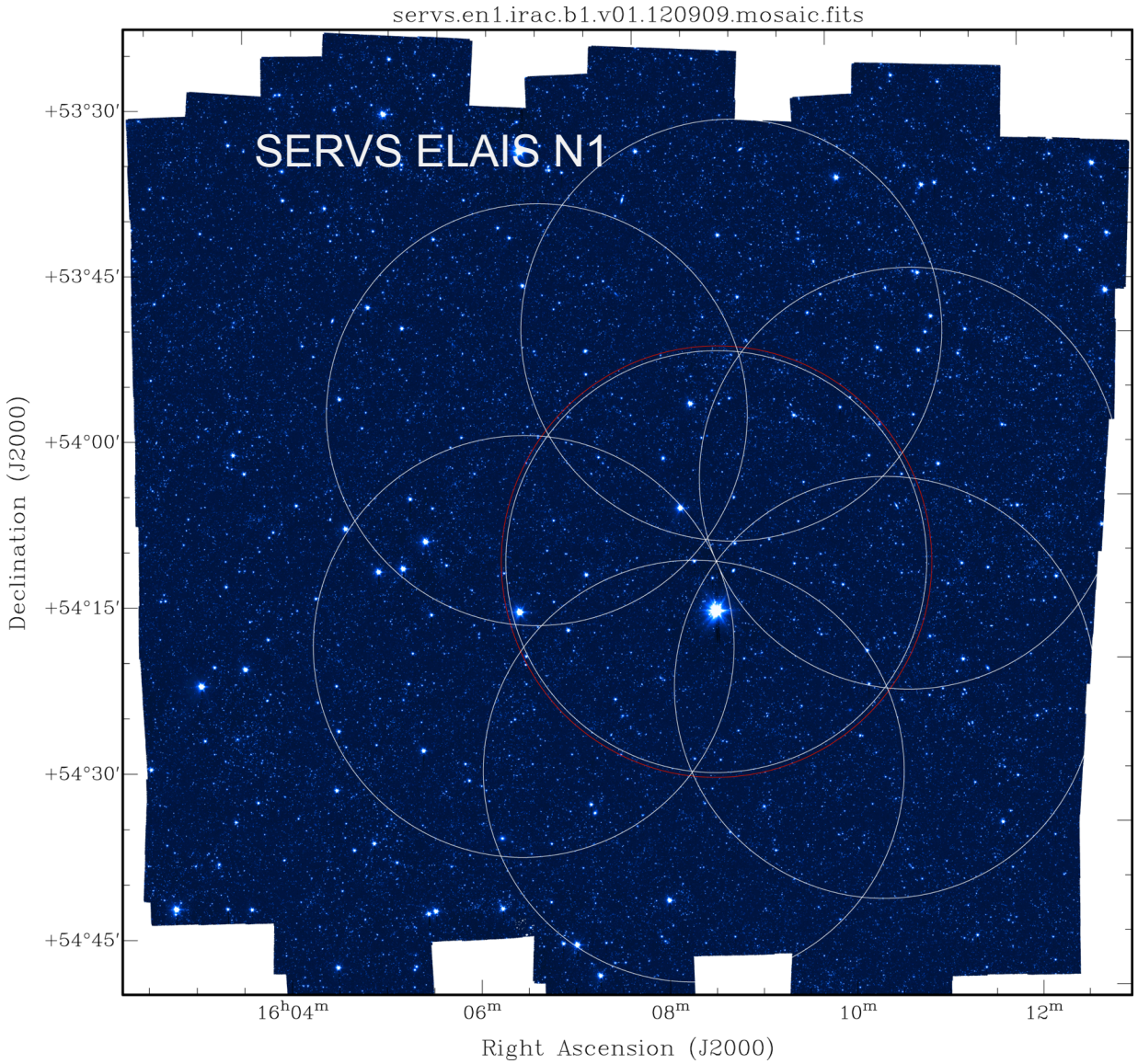
JVLA Canadian WIDAR correlator

- 90 hours observing 2011/14
  - 4-6 GHz
  - 60 hours B & C configuration
  - 30 hours A configuration (in process)

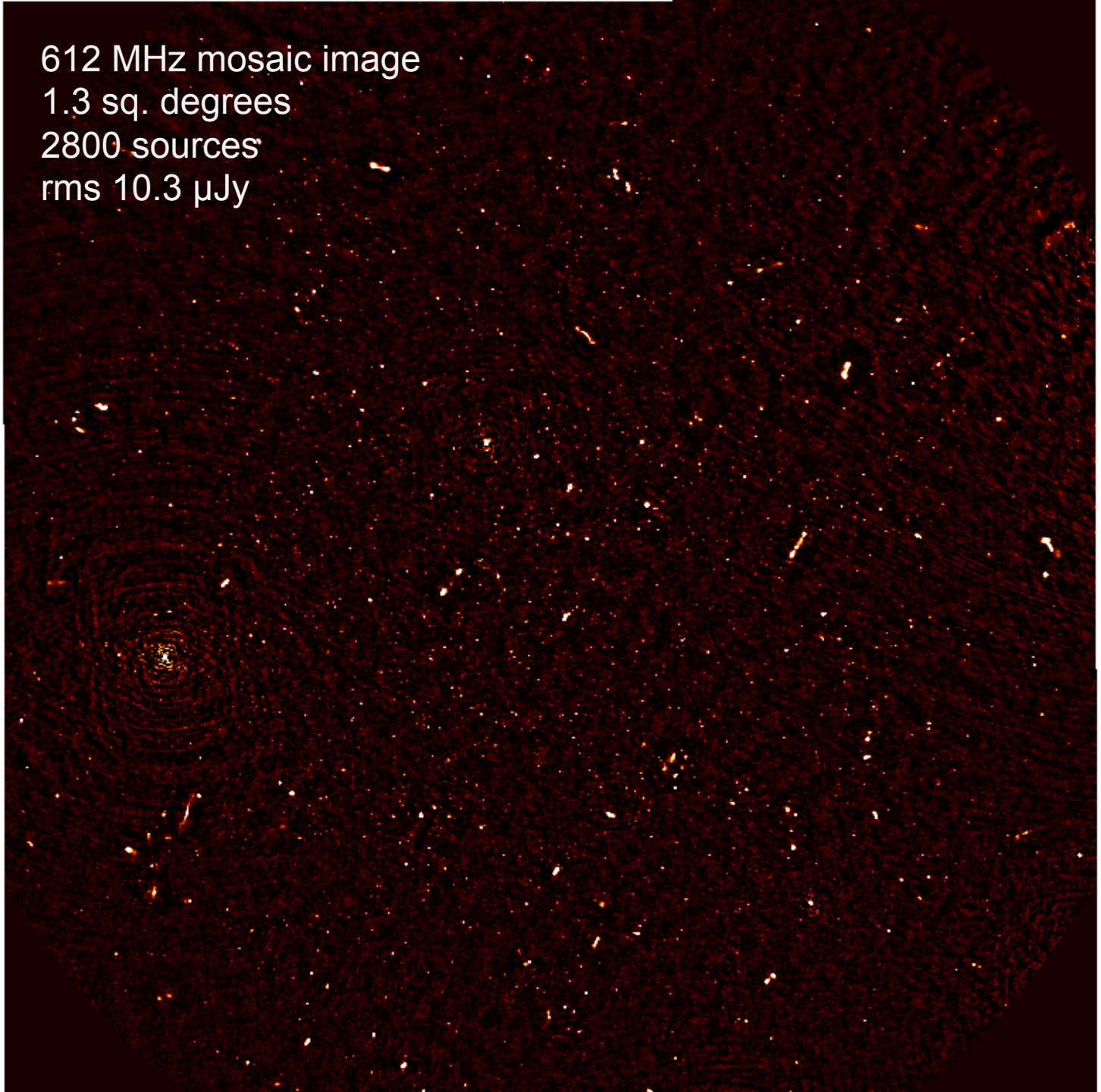
GMRT/JVLA Deep Polarization Fields Team

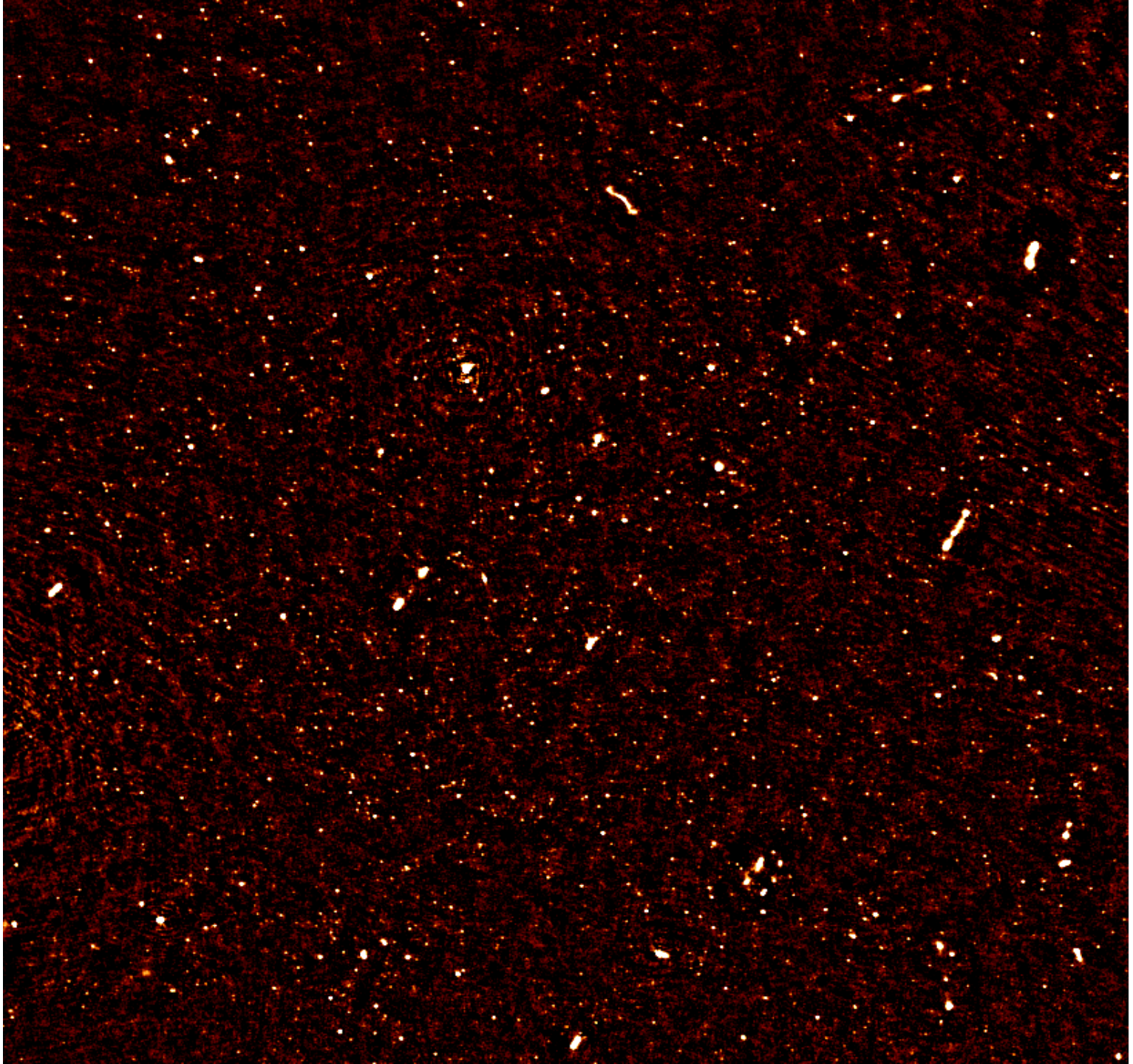
Julie Banfield	CSIRO
Sanjay Bhatnagar	NRAO
Jim Condon	NRAO
David Green	Cambridge University
Preshanth Jagannathan	University of Cape Town / NRAO
Nimisha Kantharia	NCRA
Roland Kothes	Herzberg Institute of Astrophysics
Rick Perley	NRAO
Jeroen Stil	University of Calgary
Russ Taylor (PI)	University of Cape Town & the Western Cape
Jasper Wall	University of British Columbia
Tony Willis	DRAO

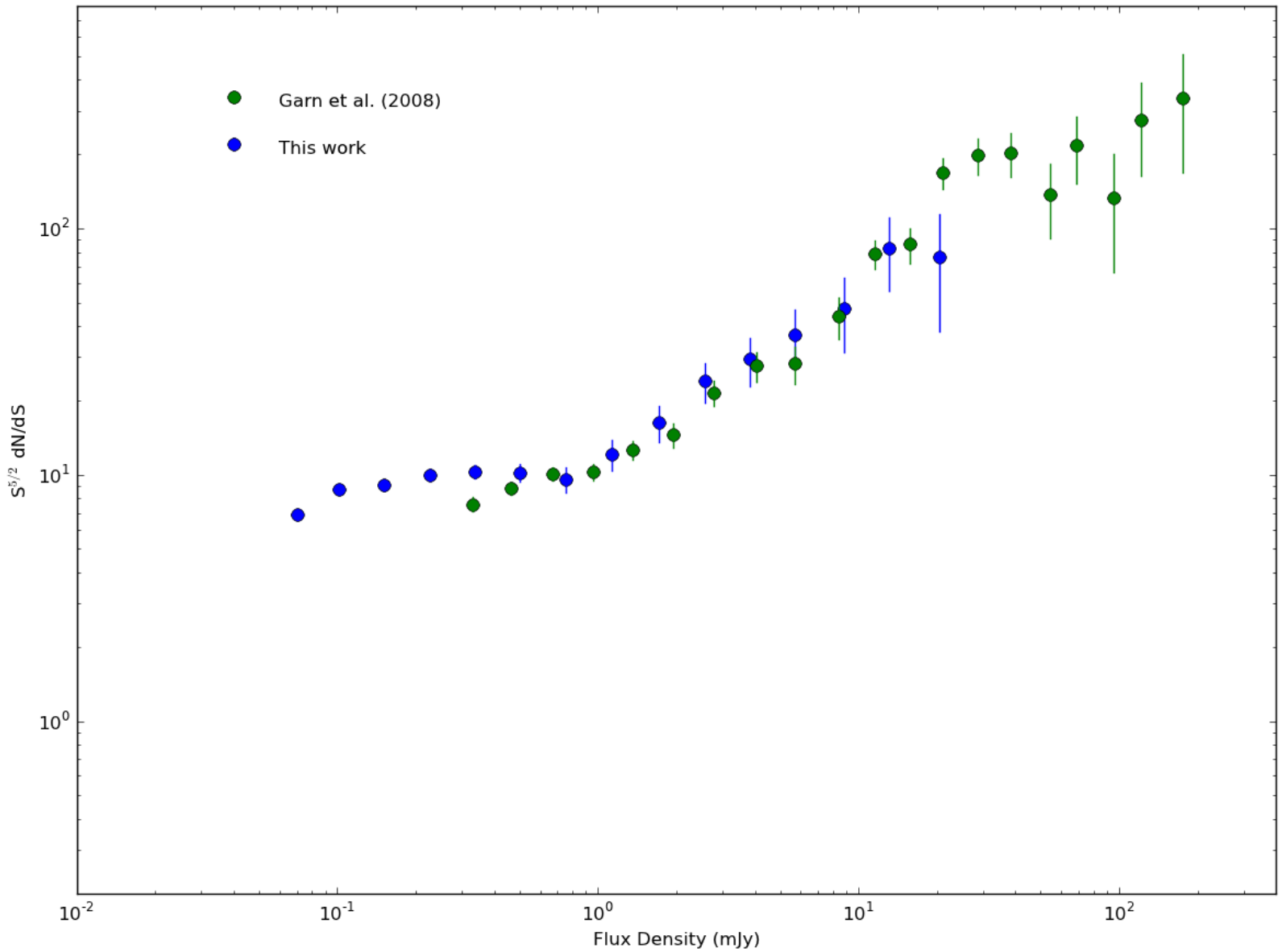
GMRT ultra-deep Polarization Field

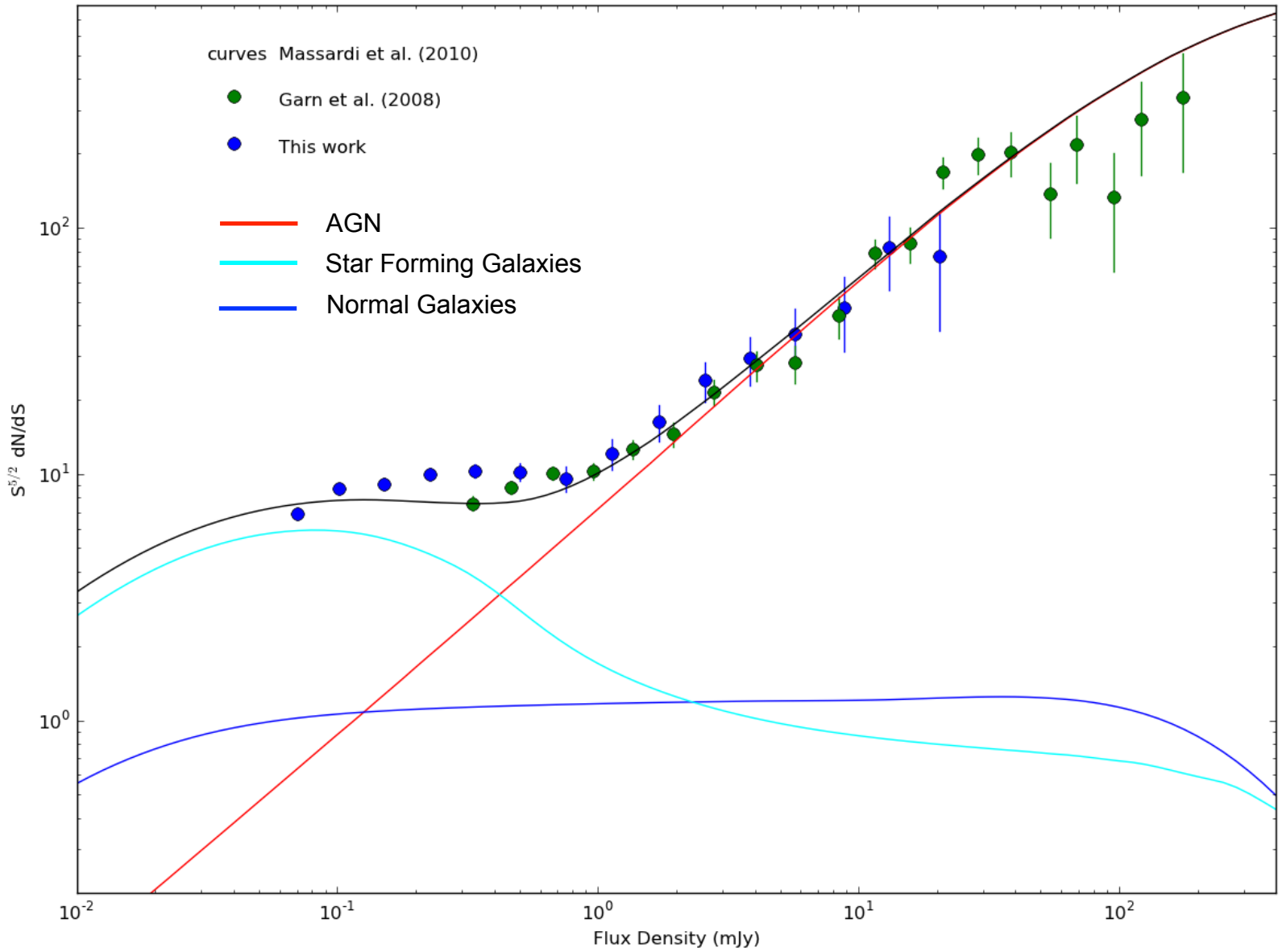


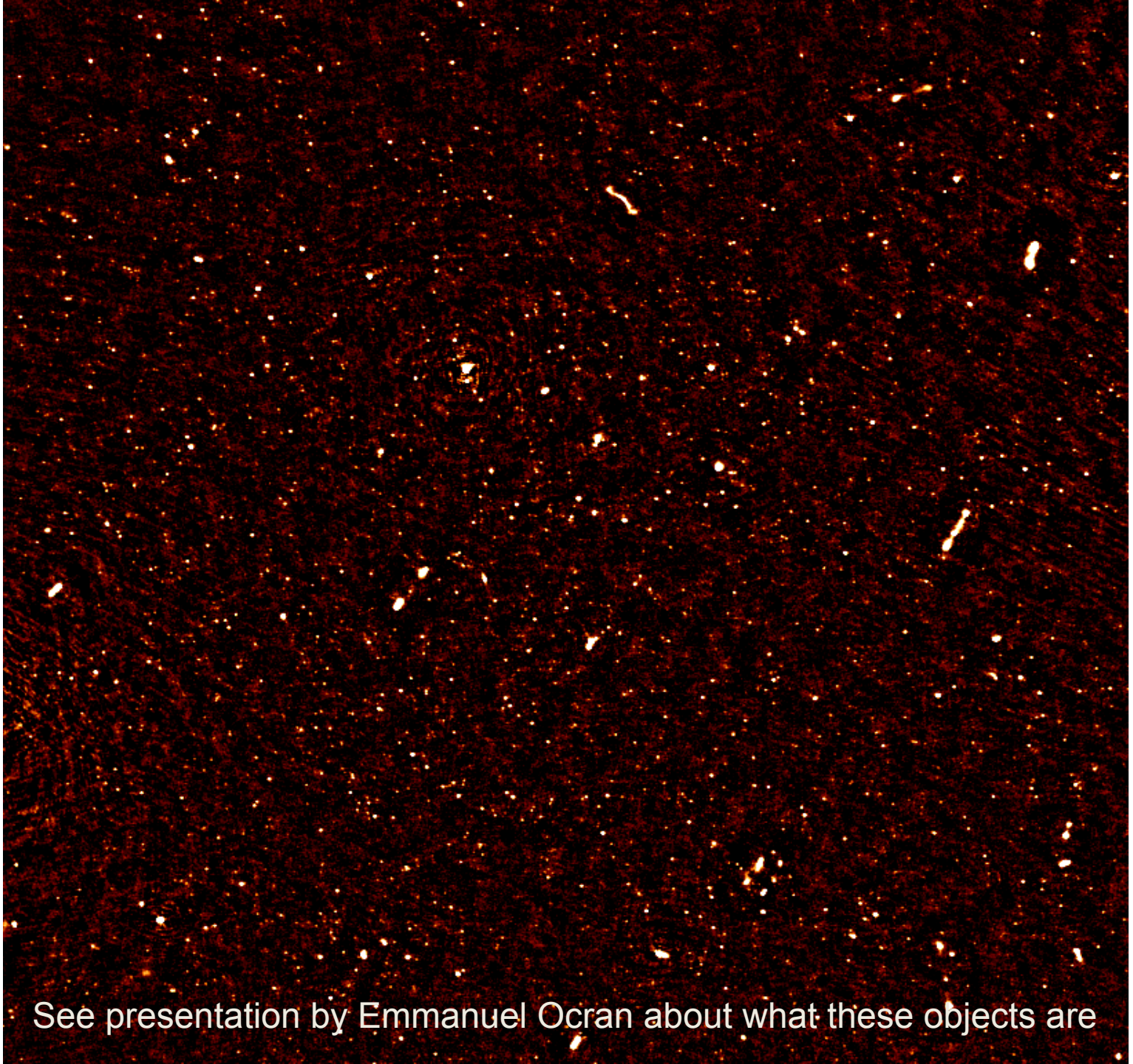
Spitzer Extragalactic Representative Volume Survey (Mauduit et al. 2012, PASP, 124, 714)


612 MHz mosaic image
1.3 sq. degrees
2800 sources
rms 10.3 μJy




Garn et al. (2008)
This work
$S^{5/2}$ dN/dS
10^2
10^1
10^0
10^{-2}
10^{-1}
10^0
10^1
10^2
Flux Density (mJy)


curves Massardi et al. (2010)
Garn et al. (2008)
This work
AGN
Star Forming Galaxies
Normal Galaxies
$S^{5/2}$ dN/dS
Flux Density (mJy)
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}



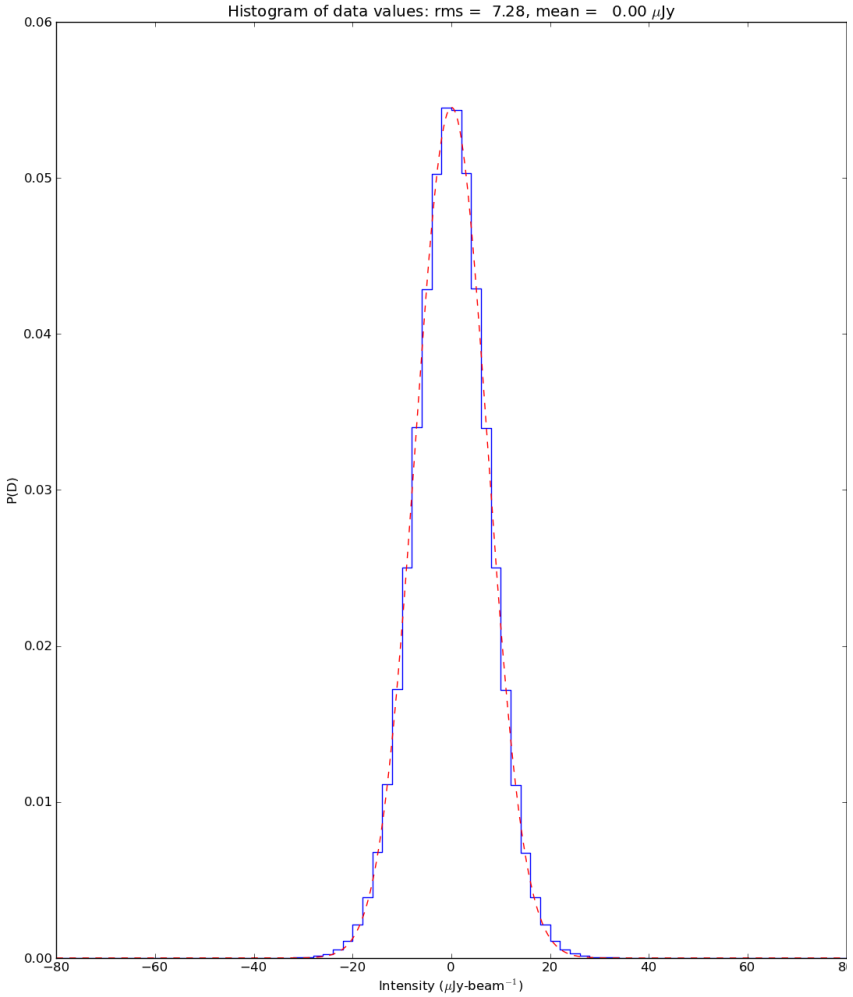
See presentation by Emmanuel Ocran about what these objects are

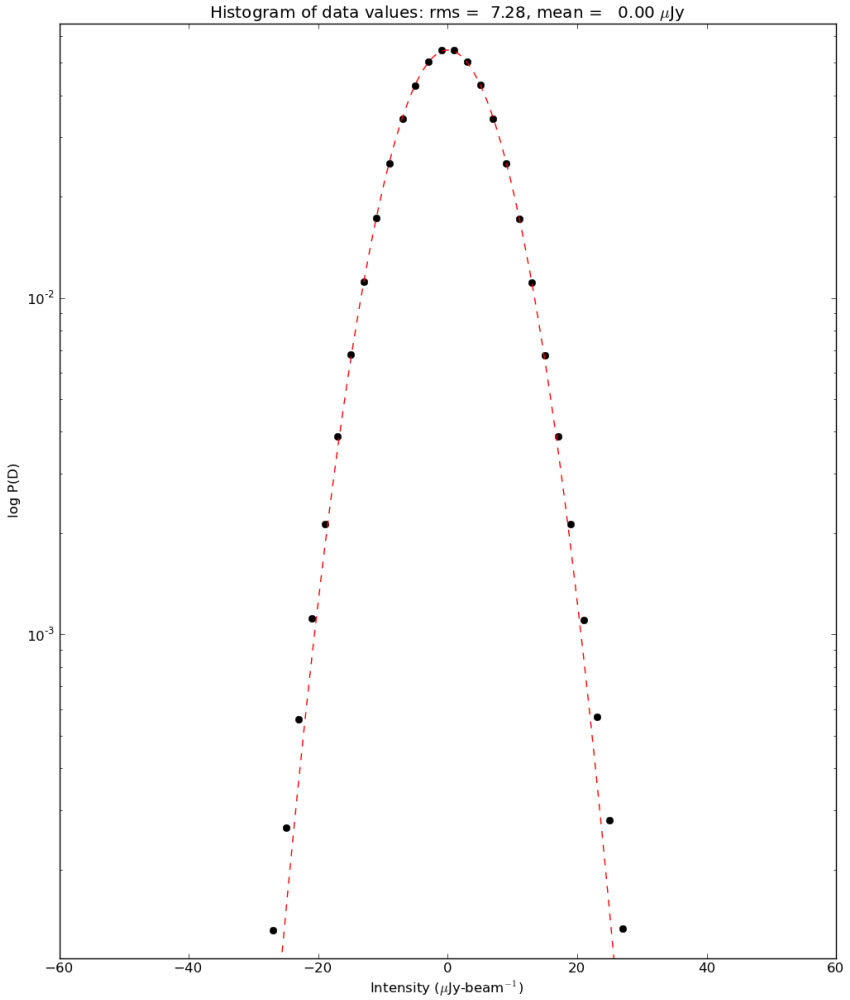

rms 7.3 μJy

Stokes Q P(D)

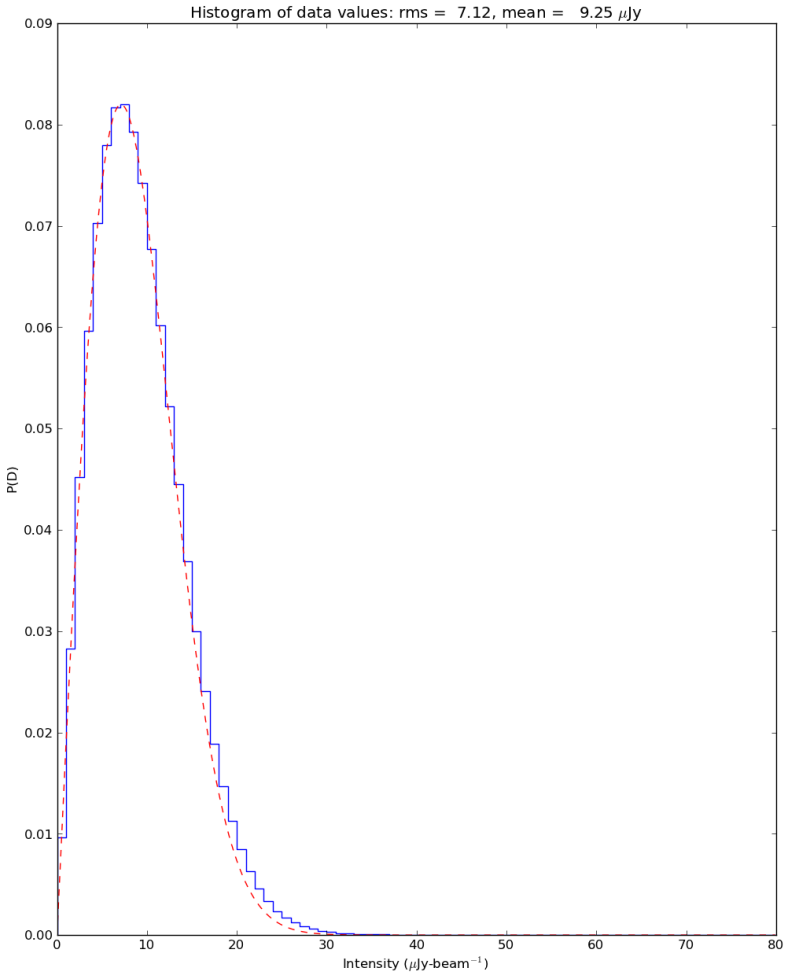
rms = 7.28 μJy

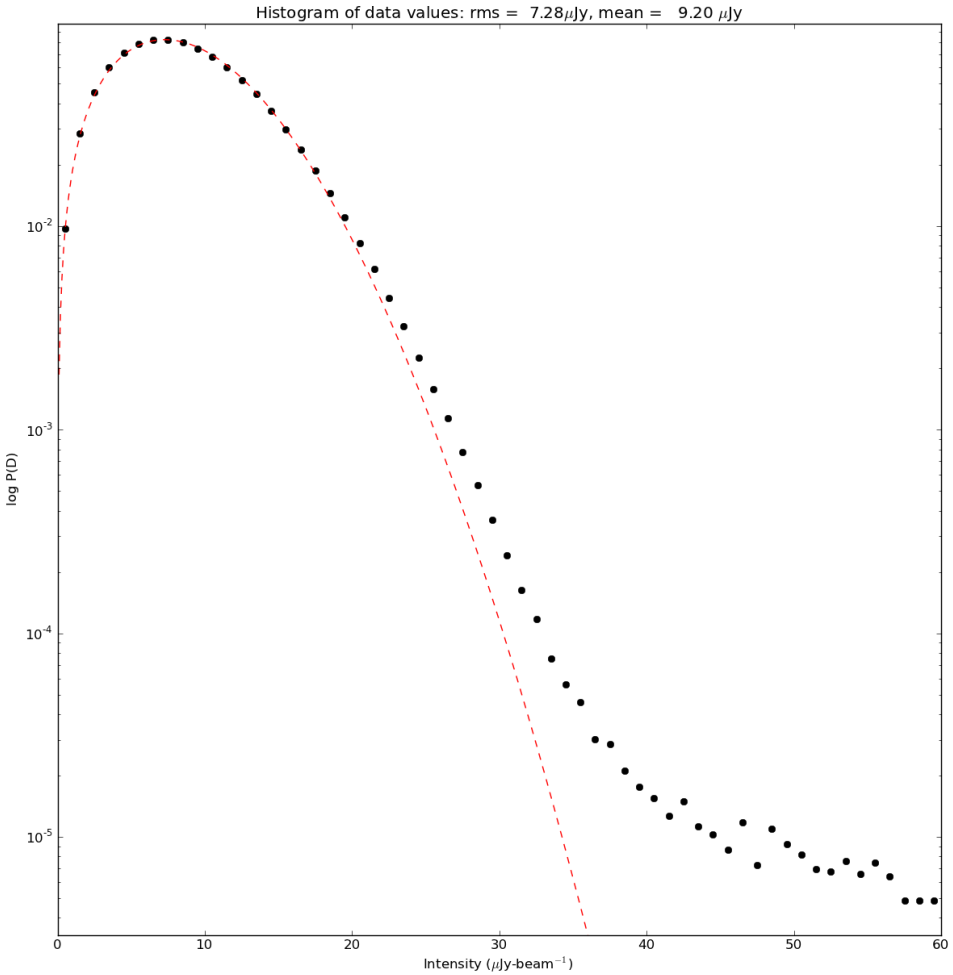
(3.7μJy @ 1.4 GHz)



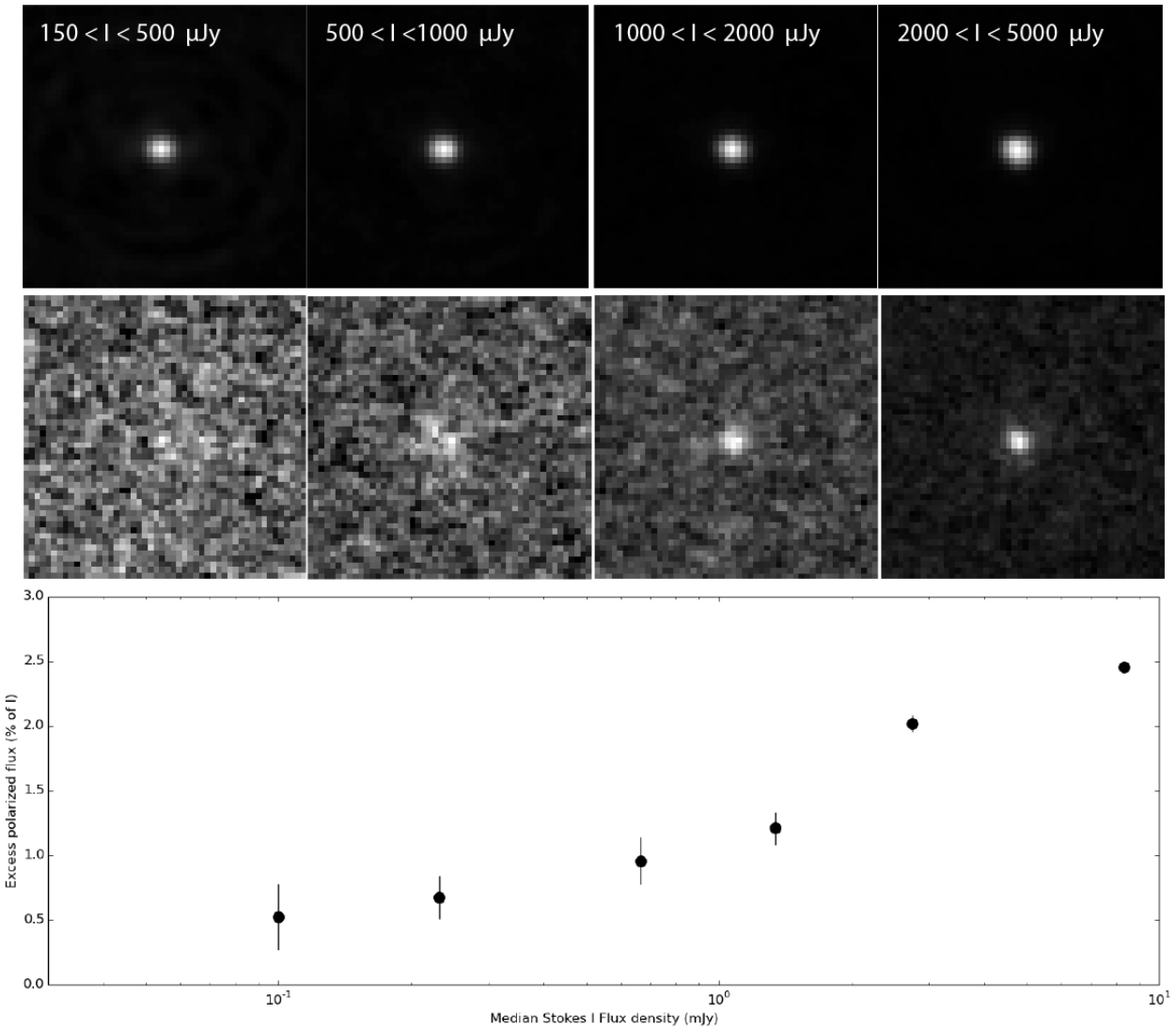


Polarized Intensity P(D)





Polarization Stacking in Stokes I flux density



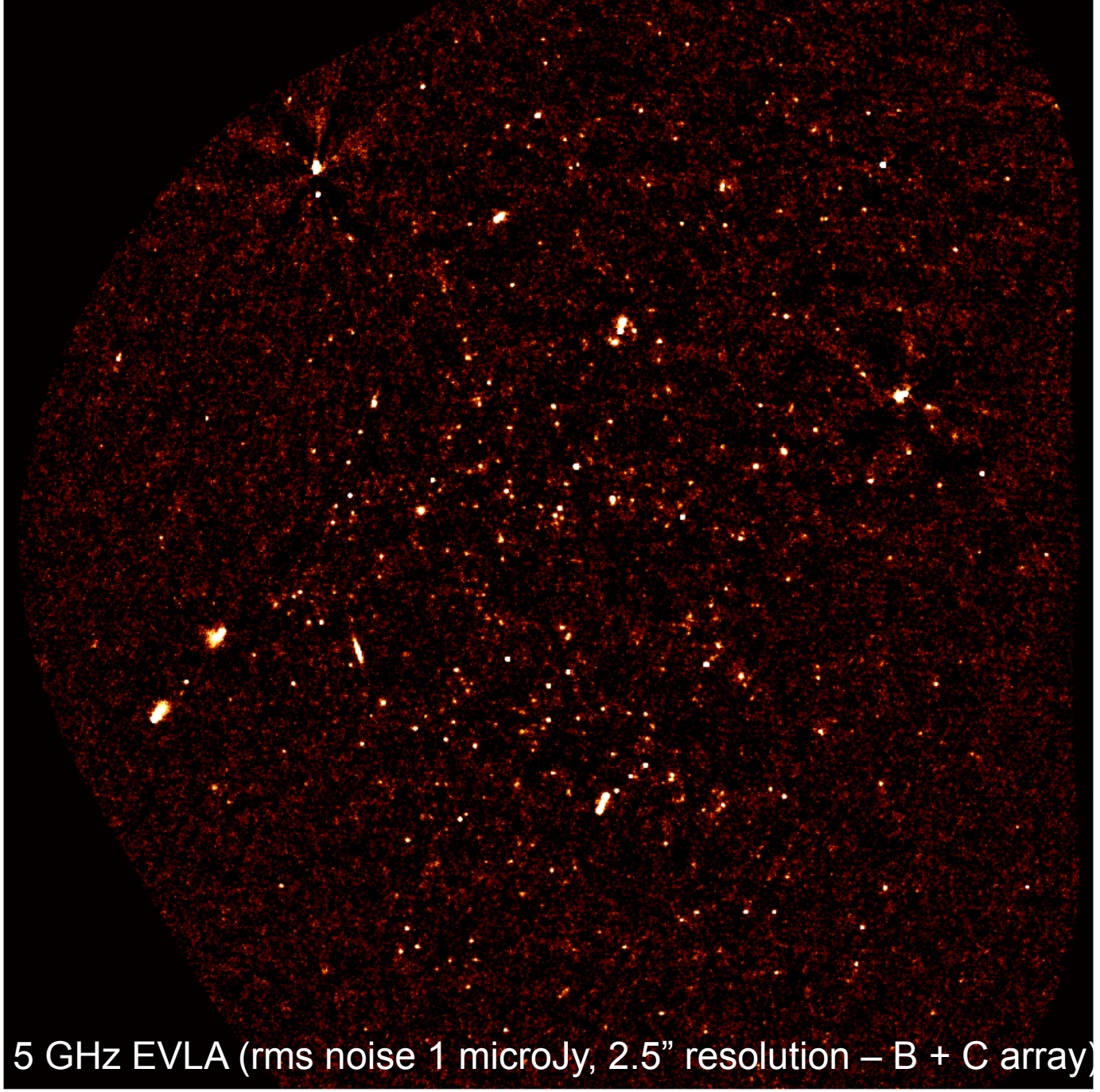
EVLA ultra-Deep 5 GHz Polarization Field

Background central region of 0.61 GHz GMRT image

+55°00′
+54°50′
+54°40′
+54°30′
+54°20′
+54°10′

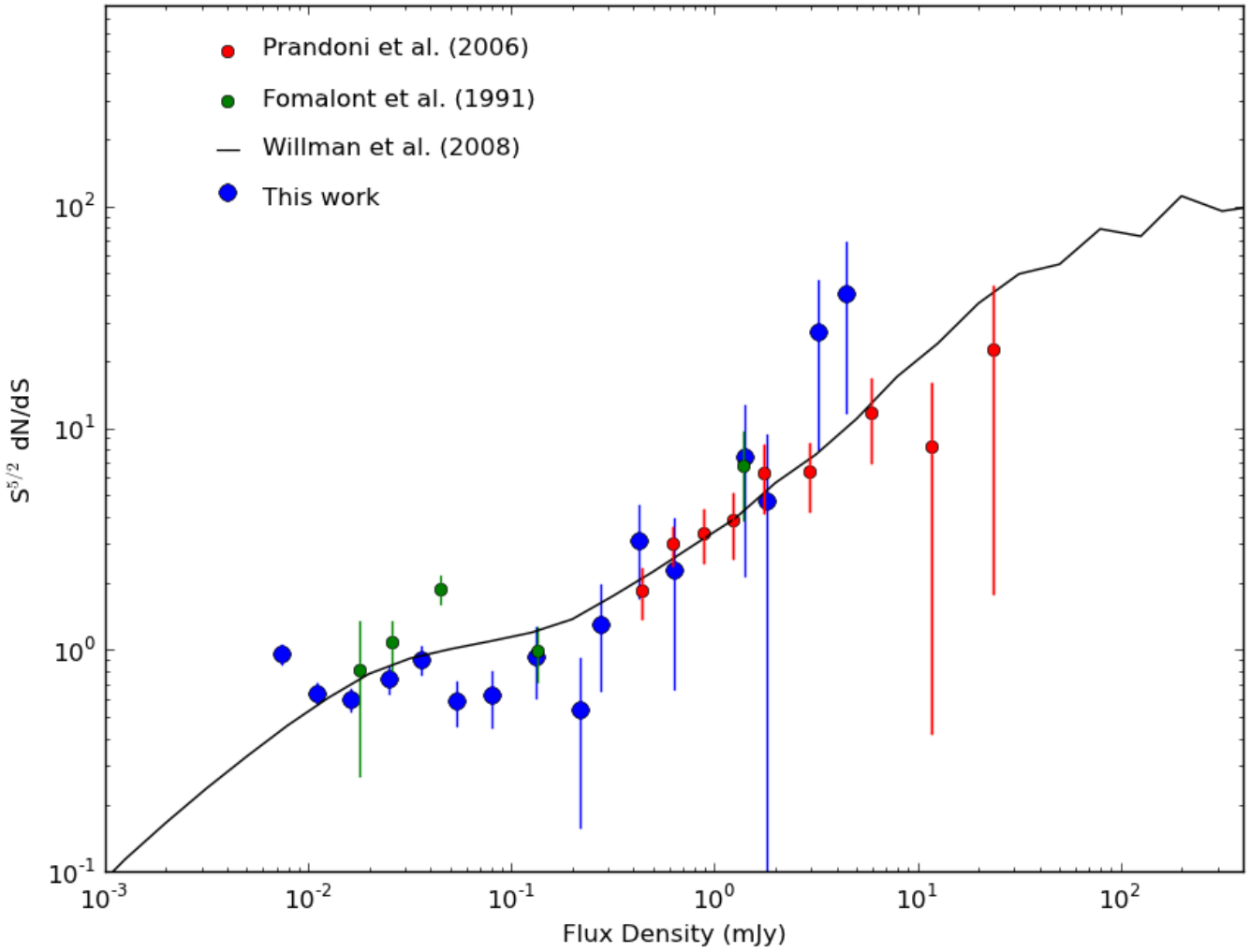
Declination (J2000)

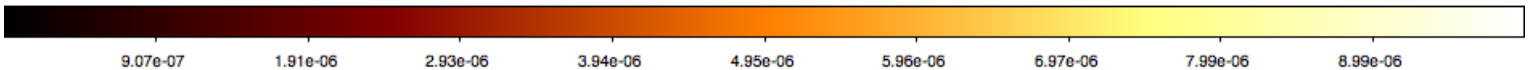
16^h12^m 10^m 08^m

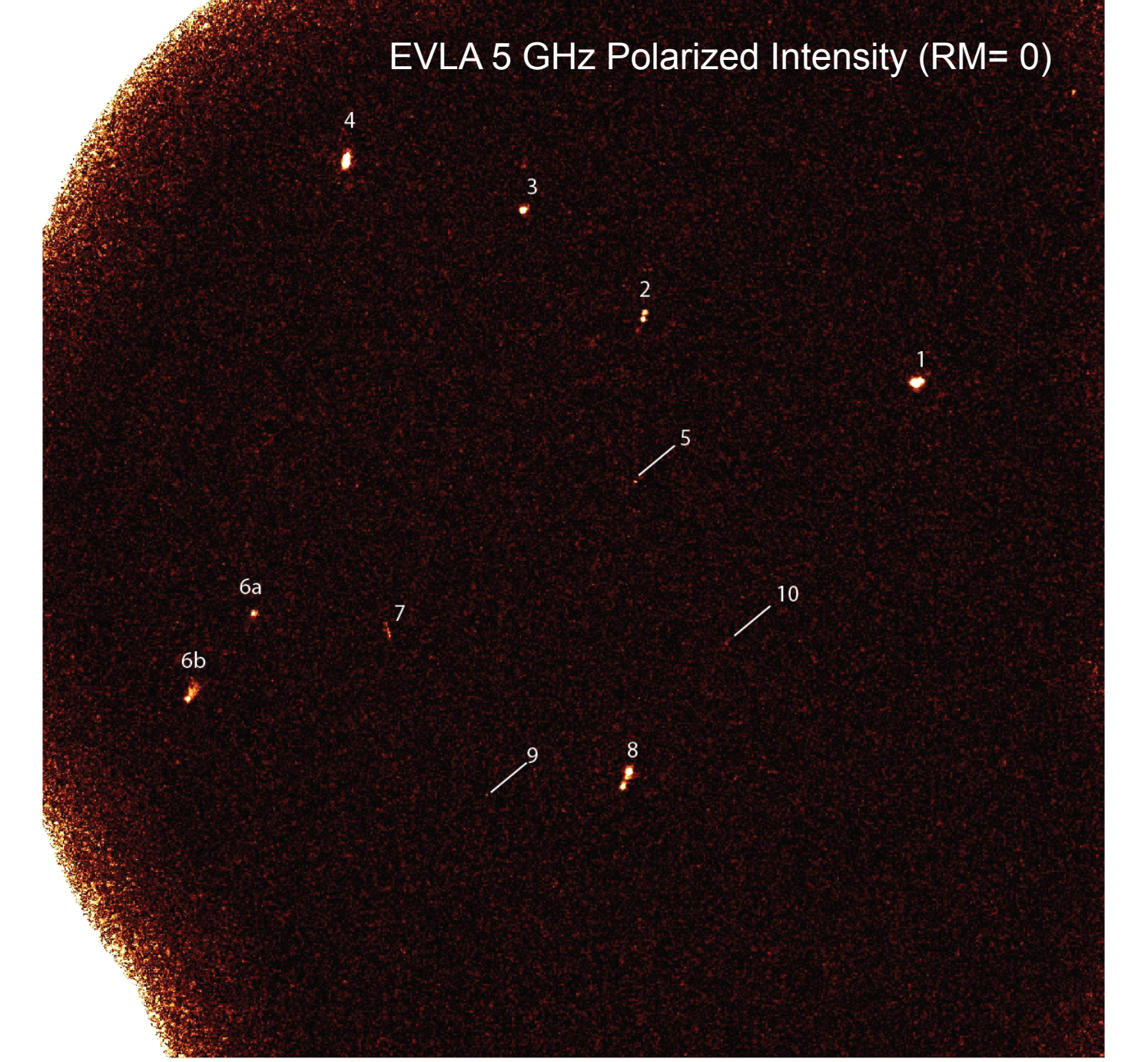

5 GHz EVLA (rms noise 1 microJy, 2.5” resolution – B + C array)
9.07e-07
1.91e-06
2.93e-06
3.94e-06
4.95e-06
5.96e-06
6.97e-06
7.99e-06
8.99e-06

5 GHz Source Counts Stokes I

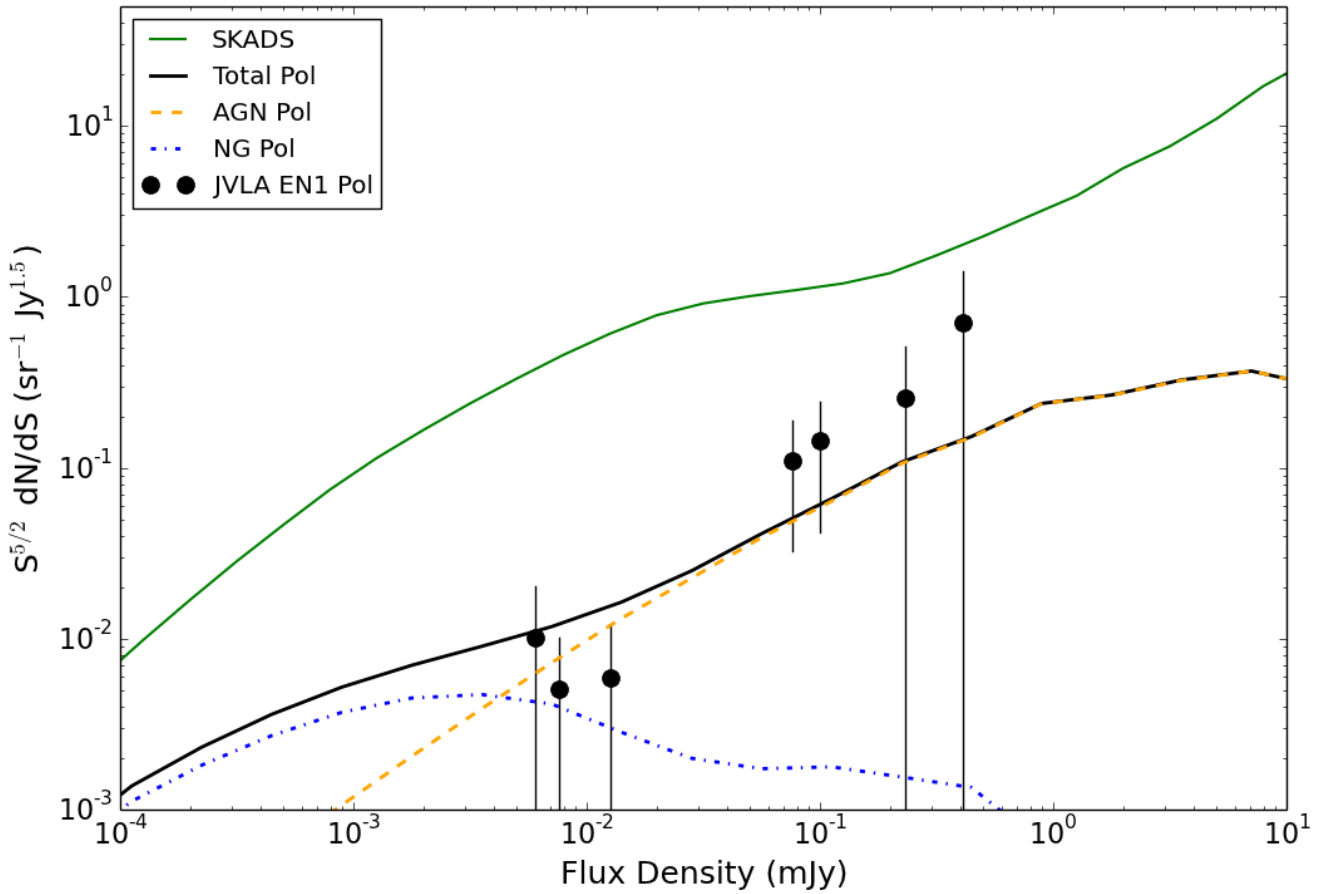
483 source detected (SAD) (~4500 per sq deg)




9.07e-07
1.91e-06
2.93e-06
3.94e-06
4.95e-06
5.96e-06
6.97e-06
7.99e-06
8.99e-06


EVLA 5 GHz Polarized Intensity (RM= 0)
4
3
2
1
5
6a
7
10
6b
9
8
1.90e-06
2.79e-06
3.70e-06
4.60e-06
5.50e-06
6.40e-06
7.30e-06
8.21e-06
9.10e-06

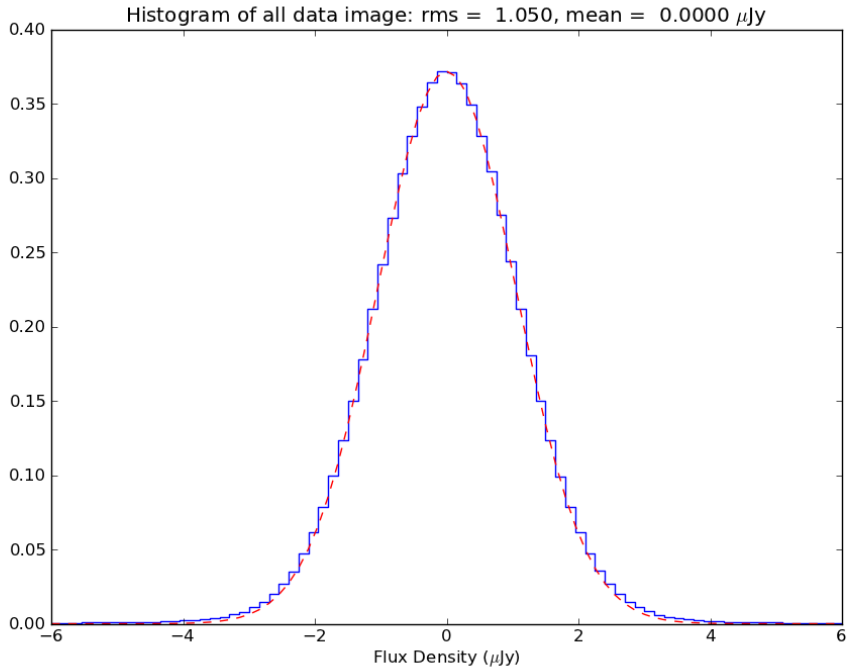
5 GHz polarized source counts



ELAIS N1 Taylor et al. 2014

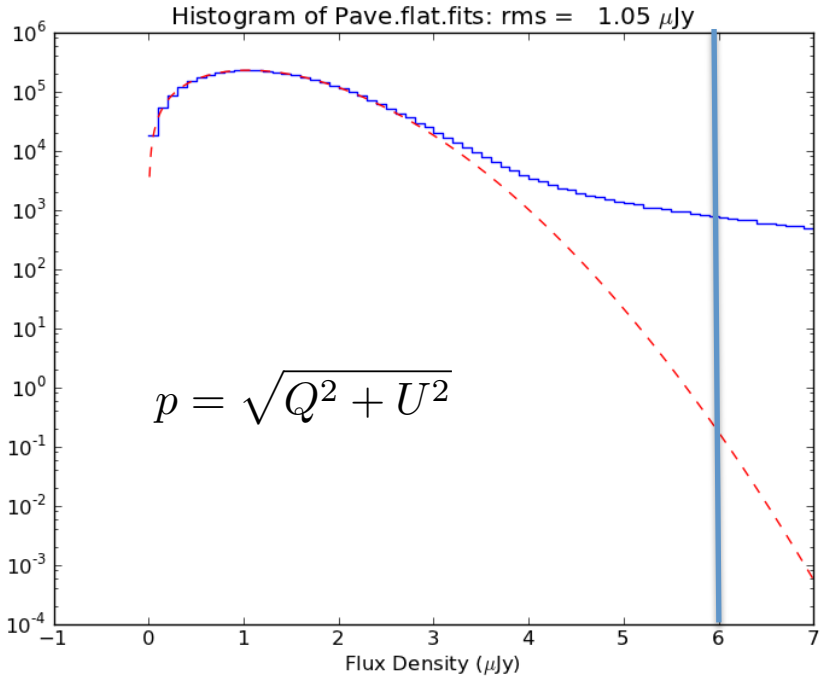
Image Pixel Amplitude distributions

Stokes Q



Gaussian Distribution σ = 1.05 μJy

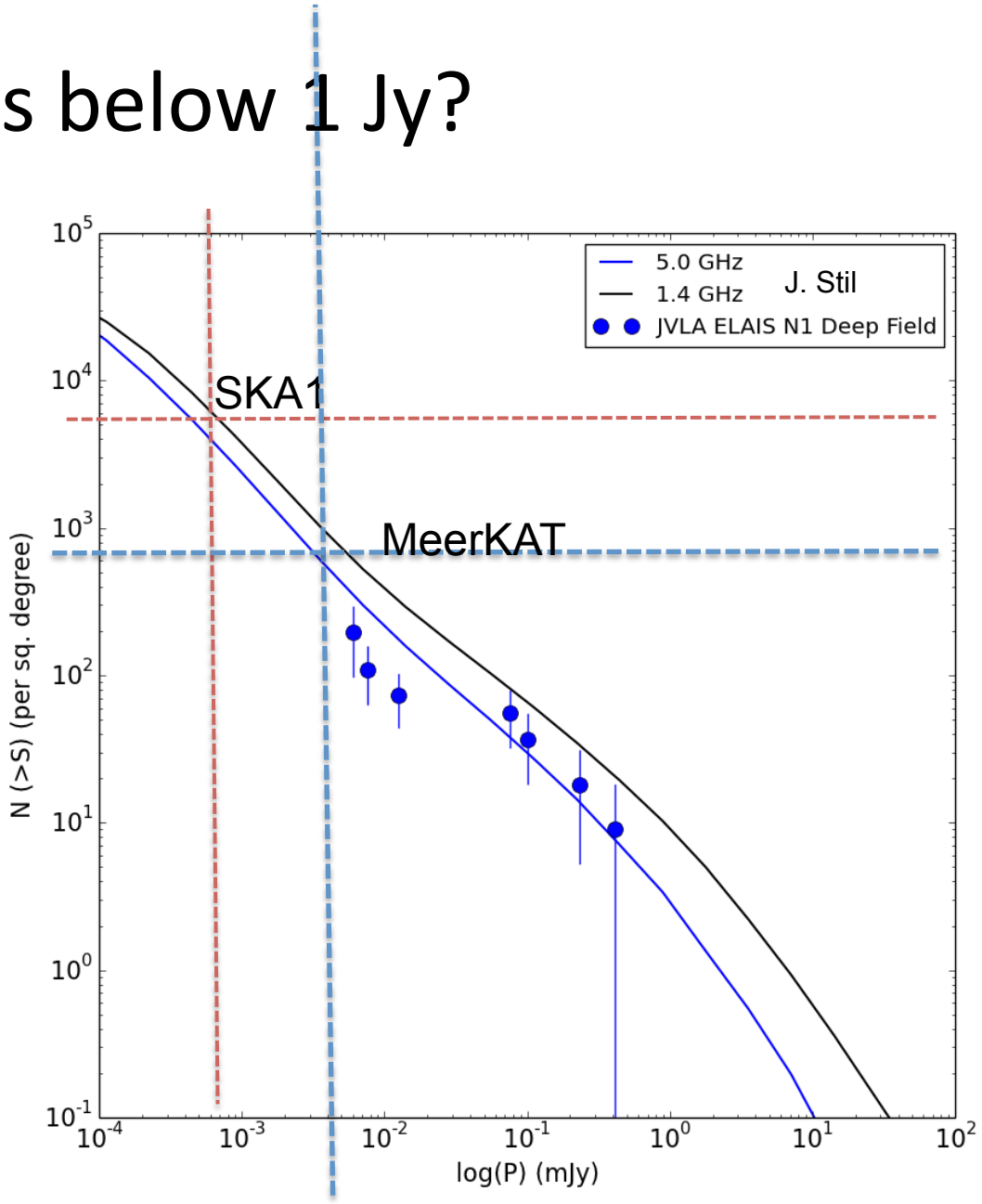
Polarized Intensity



Rayleigh Distribution for σ = 1.05 μJy

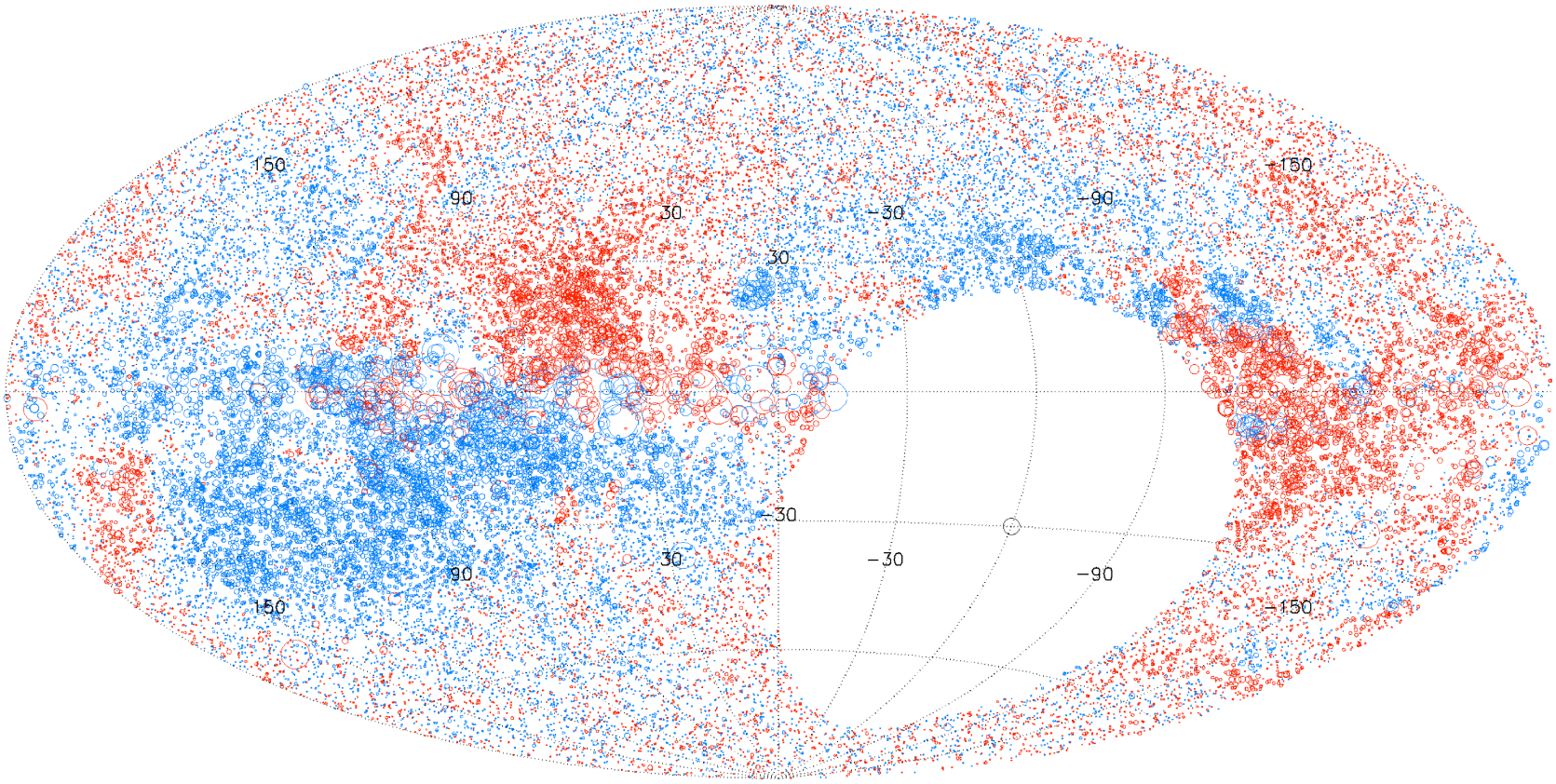
How many galaxies below 1 Jy?

- MeerKAT
  500 galaxies per sq deg
  15,000 galaxies
- RM with 1 rad m^{-1} precision with average separation of a few arcminutes



Detecting the magnetic cosmic web

$RM = RM_{object} + RM_{IGM} + RM_{MW}$

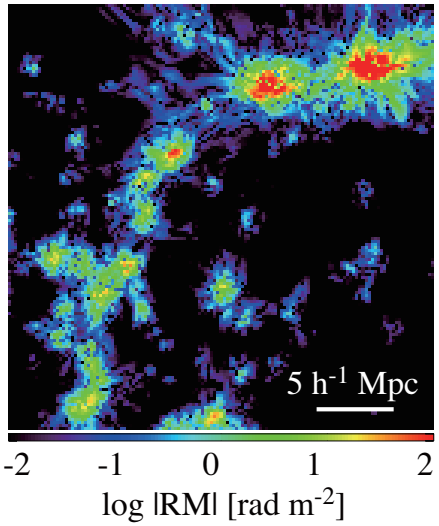


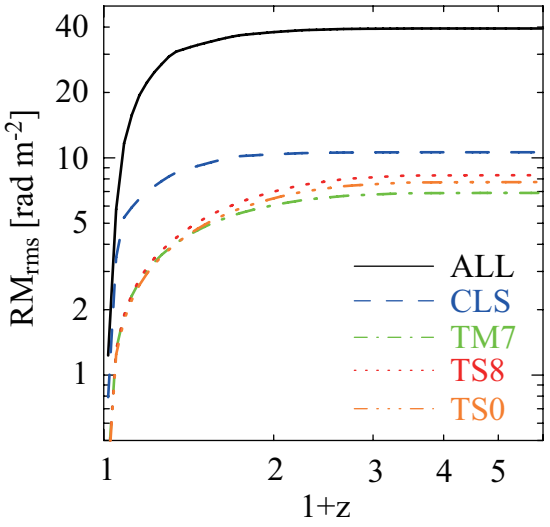
1 RM per square degree

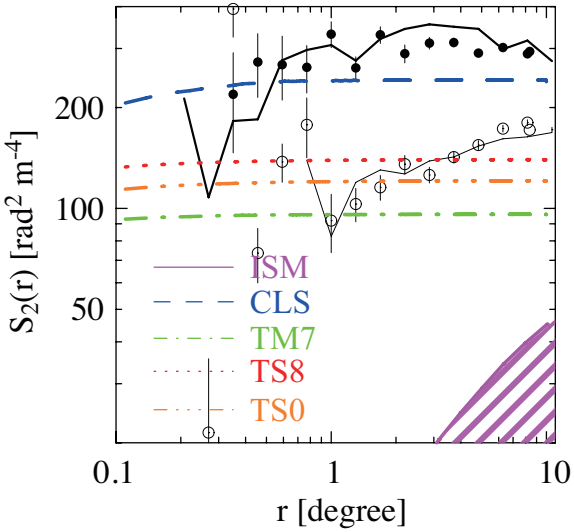
Taylor, Stil & Sunstrum (2009)

RM Signature of the Magnetism in the Cosmic Web

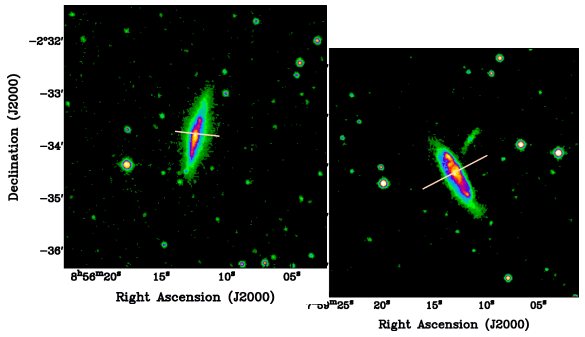
Takuya & Rhy (2011)



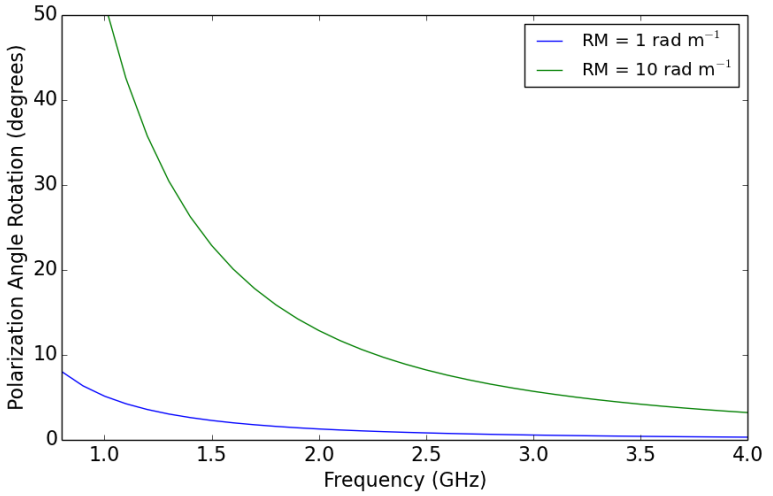




"Weak" Faraday Rotation?



50,000 galaxies



ultra-deep wide-band (sub-microJy) polarization surveys…

- 3rd Generation calibration algorithms need to be implemented and pipelined
  - Pointing self-calibration
  - Full-stokes direction dependent corrections (A-term)
  - Wide-band polarization imaging (multi-frequency synthesis and RM synthesis)
  - Simultaneous w-term, A-term and mosaicing
- Nature of the microJy Sky
- Statistical approaches to aggregate signals below then noise..