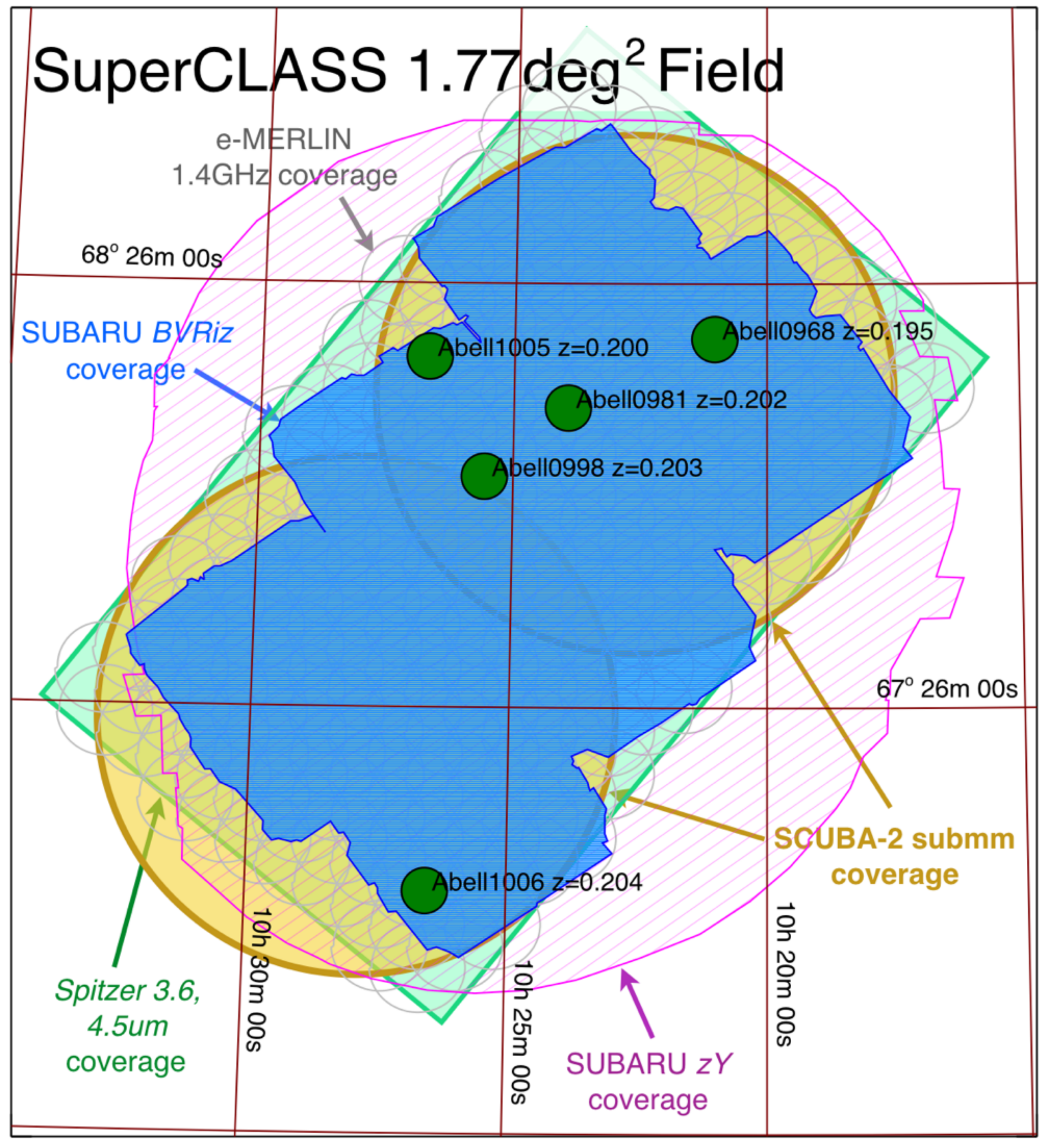
WIDE, DEEP AND LOW: A LOW-FREQUENCY STUDY OF THE SUPER-CLASS SUPER-CLUSTER WITH LOFAR AND THE GMRT

C. J. RISELEY
WITH ANNA SCAIFE, IAN HARRISON, RICHARD BATTYE & THE SUPER-CLASS COLLABORATION

SUPER-CLASS: THE SUPER-CLUSTER ASSISTED SHEAR SURVEY

- e-MERLIN legacy survey
- Primary goal: weak lensing in the radio regime
- Galaxy super-cluster
  - 5 Abell clusters
  - $z \sim 0.2$
- Multi-wavelength:
  - Also LOFAR, GMRT, JVLA, JCMT, Spitzer, SUBARU…



SUPER-CLASS: THE SUPER-CLUSTER ASSISTED SHEAR SURVEY

SuperCLASS Collaboration

MANCHESTER 1824 — The University of Manchester

Richard Battye (PI)
Michael Brown
Neal Jackson
Ian Browne
Simon Garrington
Paddy Leahy
Peter Wilkinson
Anita Richards
Scott Kay
Rob Beswick
Tom Muxlowe
Sarah Bridle
Lee Whittaker
Constantinos Demetroullas
Ian Harrison
Rafal Szepietowski
Anna Scaife
Chris Riseley

ICG Portsmouth
David Bacon
Bob Nichol

UCL
Filipe Abdalla

Durham University
Ian Small

University of Bristol
Mark Birkinshaw

The University of Nottingham
Meghan Gray

Max Planck Institute for Astrophysics
Torsten Ensslin
Mike Bell

NRAO
Steve Myers
Chris Hales

TEXAS
Caitlin Casey
Hung Chao-Ling

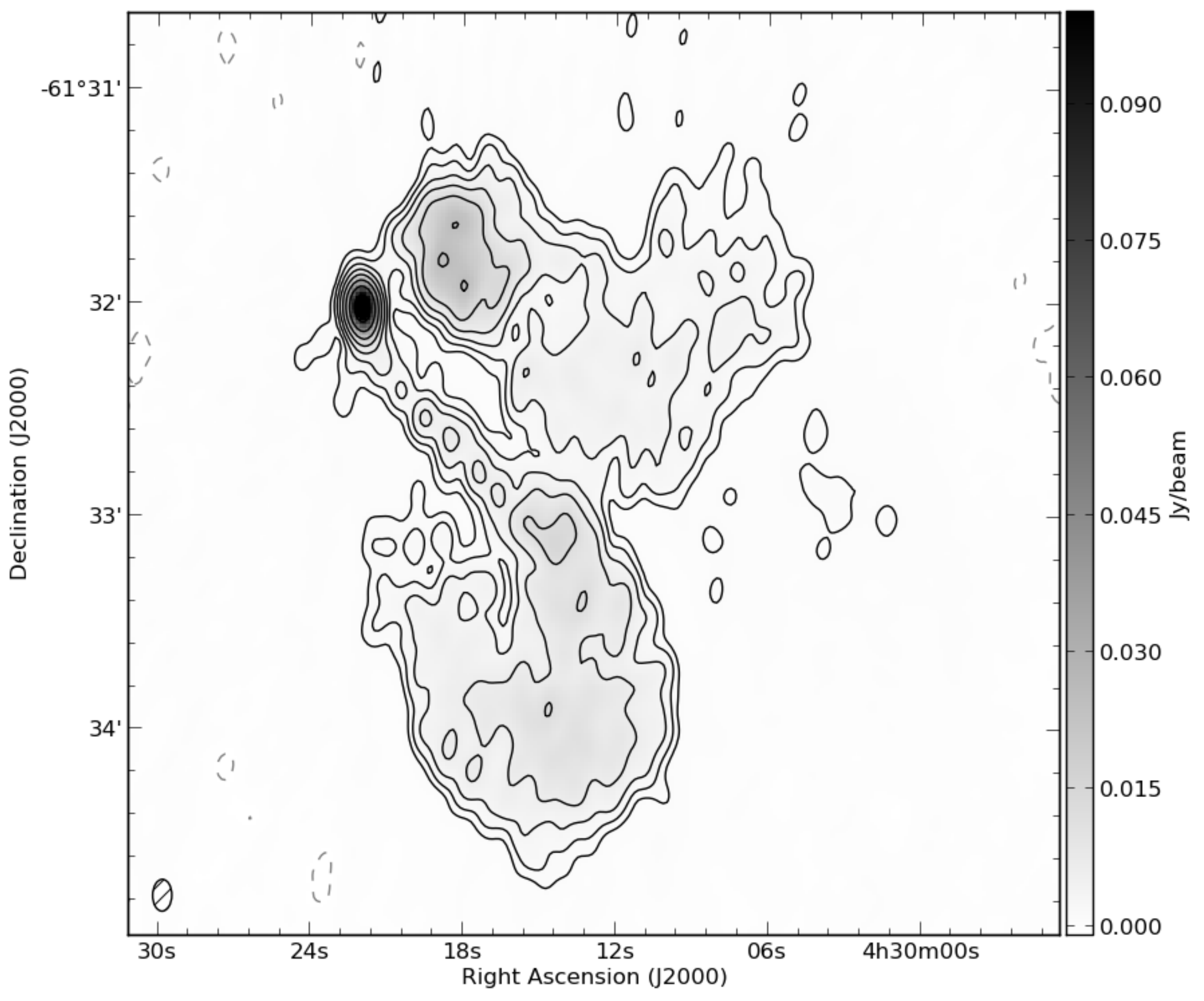
30 People

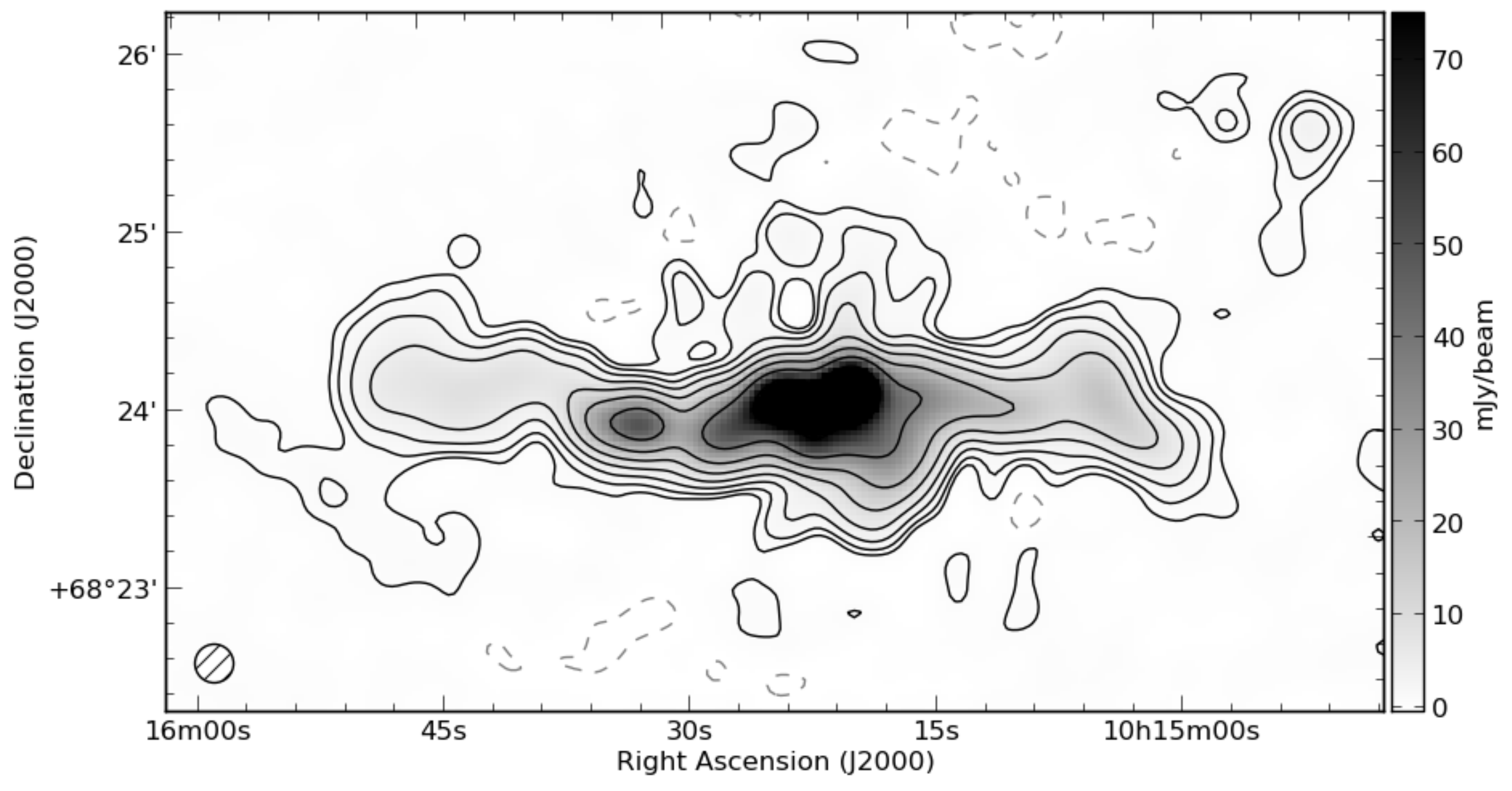
9 Institutions
3 Countries

SOURCE COUNTS

- Number of sources
- Probe populations of AGNs & SFG
- Inform cosmological models
  - Constrain population evolution
  - Confusion

$$n(S)\langle S^{2.5}\rangle = \sum_{\text{bin}} \frac{N_c}{A\Delta S}\langle S^{2.5}\rangle$$



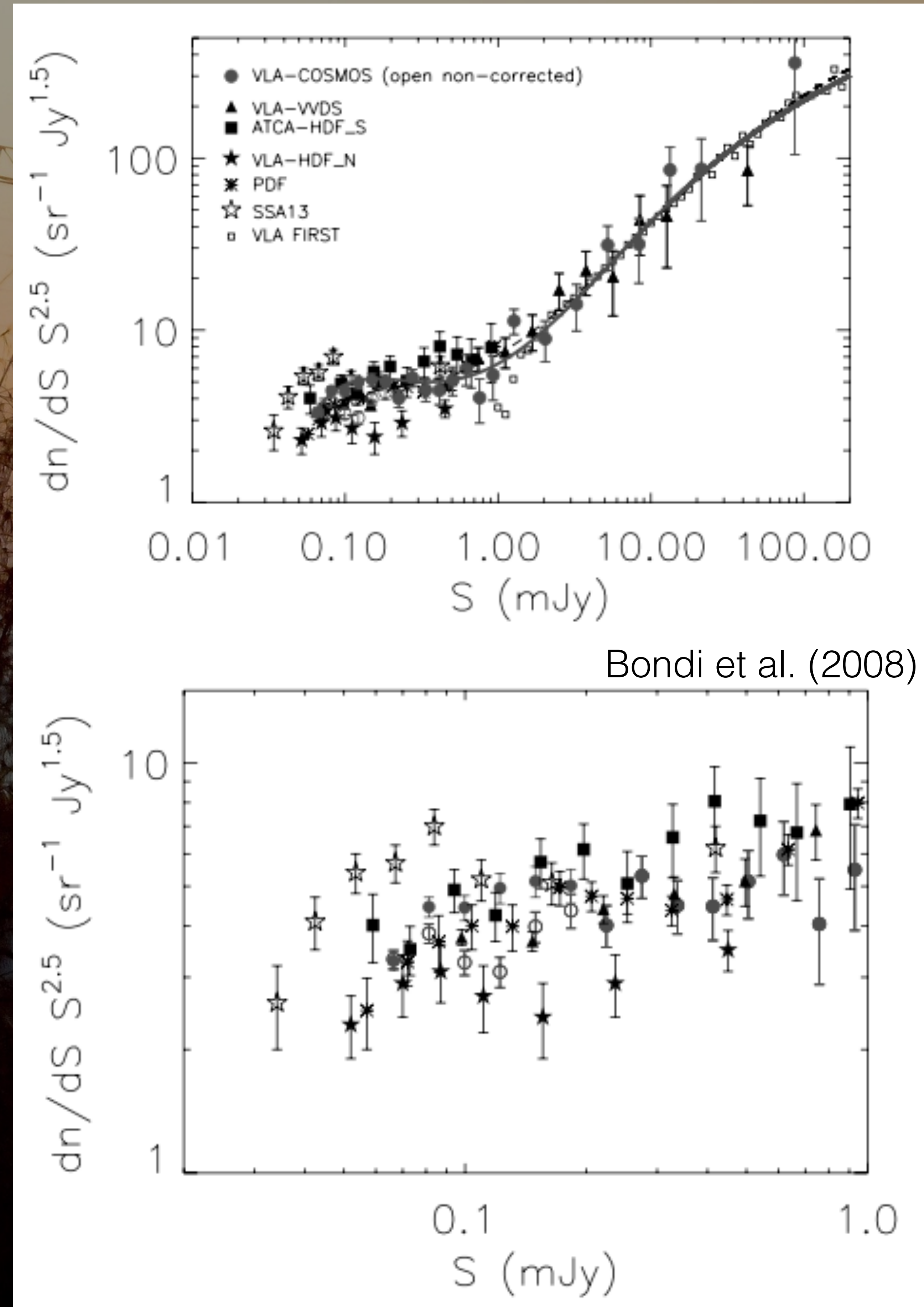


SOURCE COUNTS

Previous deep surveys:

- Large scatter - cosmic variance?
- Completeness?
- Bias?
- Source size corrections?

Various groups, various techniques



Bondi et al. (2008)

ROTATION MEASURE SYNTHESIS

- In general $\mathrm{RM} = \frac{\mathrm{d}\chi(\lambda^2)}{\mathrm{d}\lambda^2}$
- For a single source: $\chi(\lambda) = \chi_0 + \mathrm{RM} \cdot \lambda^2$
- Faraday dispersion function is Fourier relationship (Burn 1966)

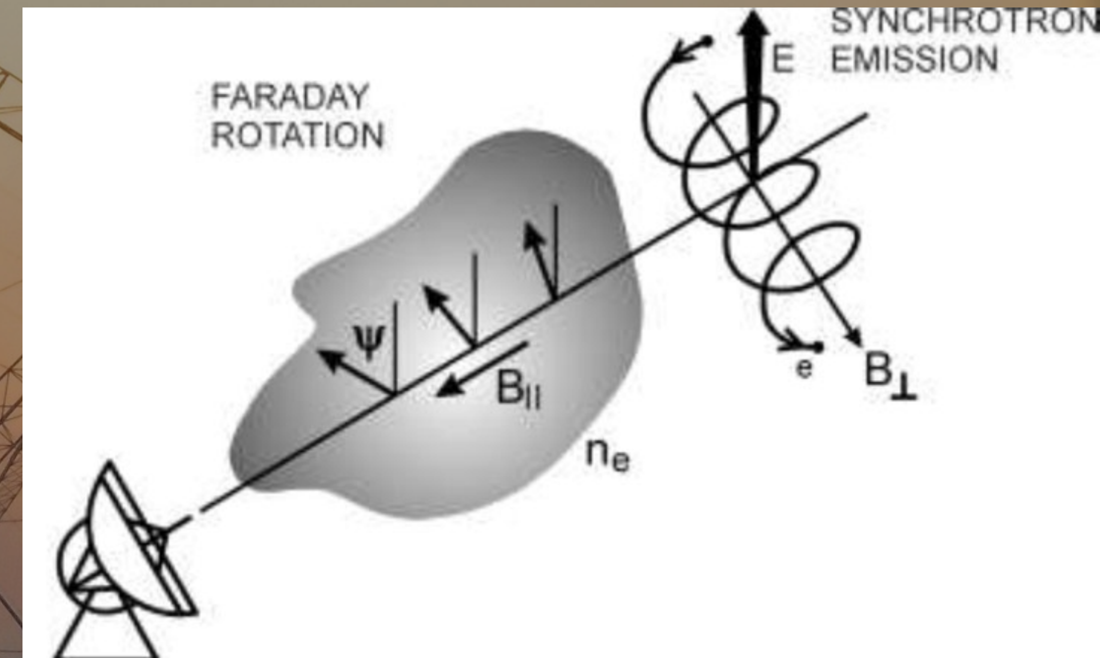
$$P(\lambda^2) = \int_{-\infty}^{+\infty} F(\phi)\, e^{2i\phi\lambda^2}\, d\phi$$

- Analogous to aperture synthesis, where *uv* plane (λ²-space) is not fully sampled (Brentjens & de Bruyn 2005)

$$\tilde{P}(\lambda^2) = W(\lambda^2)\, P(\lambda^2)$$

- The response function similar to PSF:

$$\tilde{F}(\phi) = K \int_{-\infty}^{+\infty} \tilde{P}(\lambda^2)\, e^{-2i\phi\lambda^2}\, d\lambda^2 = F(\phi) \star R(\phi)$$



- Measurement of polarized sources
  - Measurement of magnetic field along l.o.s. via

$$\mathrm{RM} = 0.812 \int_{\mathrm{l.o.s.}} \mathrm{n_e}\, \boldsymbol{B} \cdot \mathrm{d}\boldsymbol{l}$$

  - Foregrounds? Instrumental?
- RM synthesis allows component separation

A&A 441, 1217–1228 (2005)
DOI: 10.1051/0004-6361:20052990

Astronomy & Astrophysics

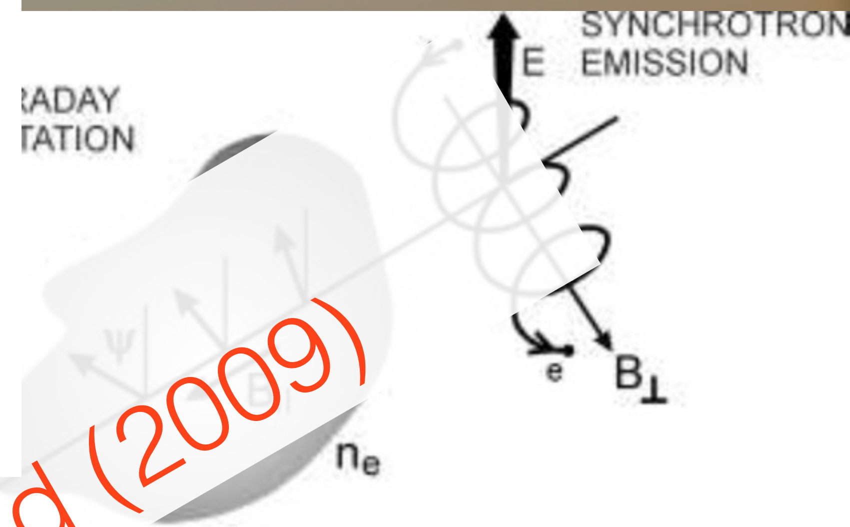
Faraday rotation measure synthesis★

M. A. Brentjens[1,2] and A. G. de Bruyn[2,1]

[1] Kapteyn Astronomical Institute, University of Groningen, PO Box 800, 9700 AV Groningen, The Netherlands
e-mail: m.a.brentjens@astro.rug.nl
[2] ASTRON, PO Box 2, 7990 AA Dwingeloo, The Netherlands

Received 4 March 2005 / Accepted 20 June 2005

NTHESIS



- Faraday dispersion function is Fourier relationship (Burn 1966)

$$P(\lambda^2) = \int_{-\infty}^{+\infty} F(\phi)\, e^{2i\phi\lambda^2}\, d\phi$$

- Analogous to aperture synthesis, where *uv* plane (λ^2-space) is not fully sampled (Brentjens & de Bruyn 2

$$\tilde{P}(\lambda^2) = W(\lambda^2)\, P(\lambda$$

- The response function s

$$\tilde{F}(\phi) = K \int_{-\infty}^{+\infty} \tilde{P}(\lambda^2)\, e^{-2i\phi\lambda^2}\, d\lambda^2$$

Measurement of polarized sources

- Measurement of magnetic field along l.o.s. via

For more detail: Brentjens & de Bruyn (2005), Heald (2009)

Cosmic Magnetic Fields: From Planets, to Stars and Galaxies
Proceedings IAU Symposium No. 259, 2008
K.G. Strassmeier, A.G. Kosovichev & J.E. Beckman, eds.

doi:10.1017/S1743921309031421

The Faraday rotation measure synthesis technique

George Heald
ASTRON, P.O. Box 2, 7990 AA Dwingeloo, The Netherlands
email: heald@astron.nl

SURVEY DESCRIPTION

GMRT:

- Cycle 25
- 325 MHz
- 30 km max baseline
- τ_{int} ~4.1h per pointing
- 6 pointings
- SPAM (Intema et al. 2009)

LOFAR:

- Cycle 0
- 115 - 160 MHz
- NL stations only
  - ~80 km max baseline
- Interleaved mode
- τ_{int} ~8h total
- Single pointing
- BBS:
  - 1st GSM sky model
  - 2nd TGSS sky model

RESULTS

GMRT:

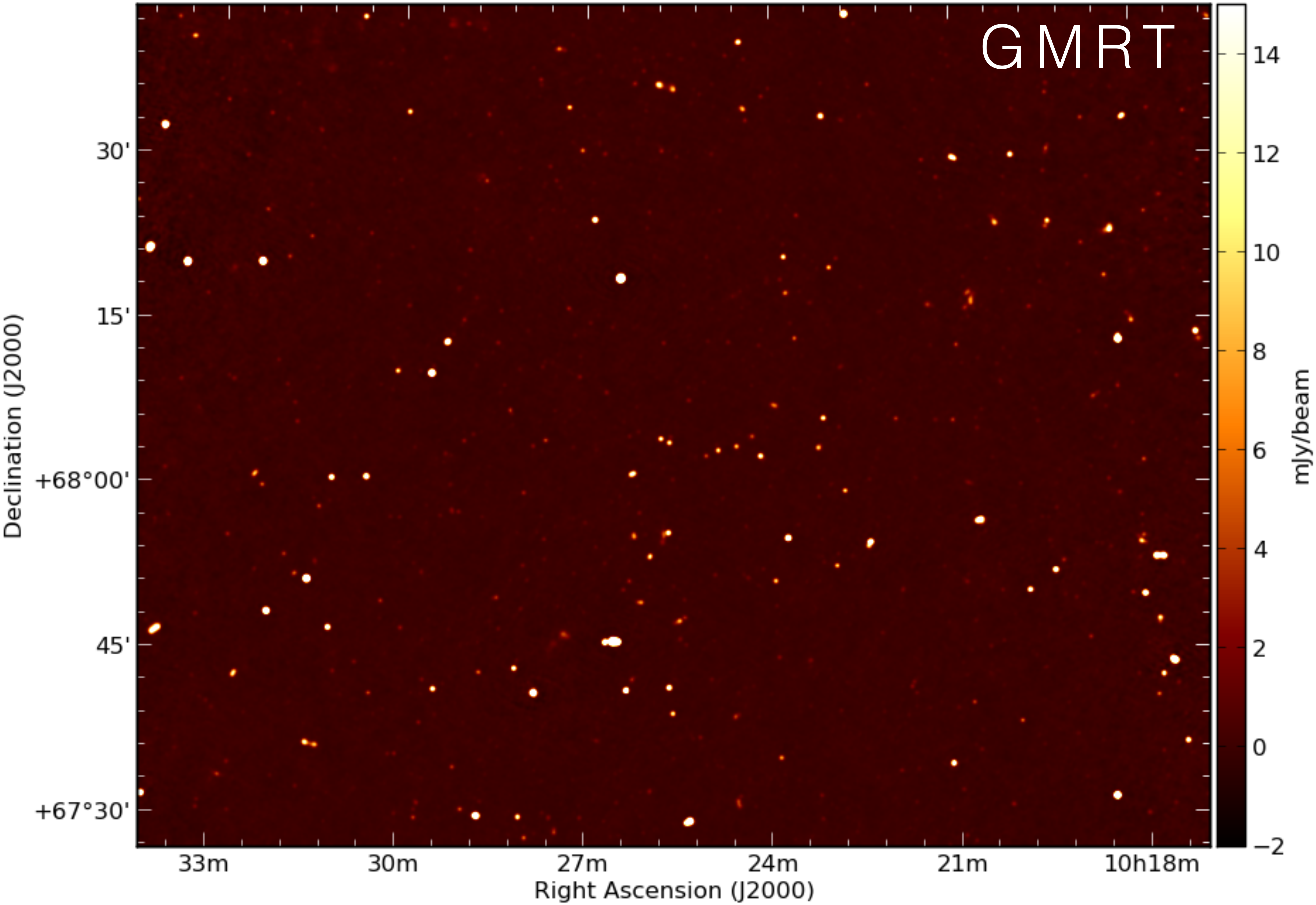
- σ_{rms} = 34 μJy/beam (mosaic)
  - 44 μJy/beam (pp)
  - 34 μJy/beam (th)
- θ = 13 arcsec
- 6.5 deg^2
- *Most sensitive 325 MHz observations to-date*

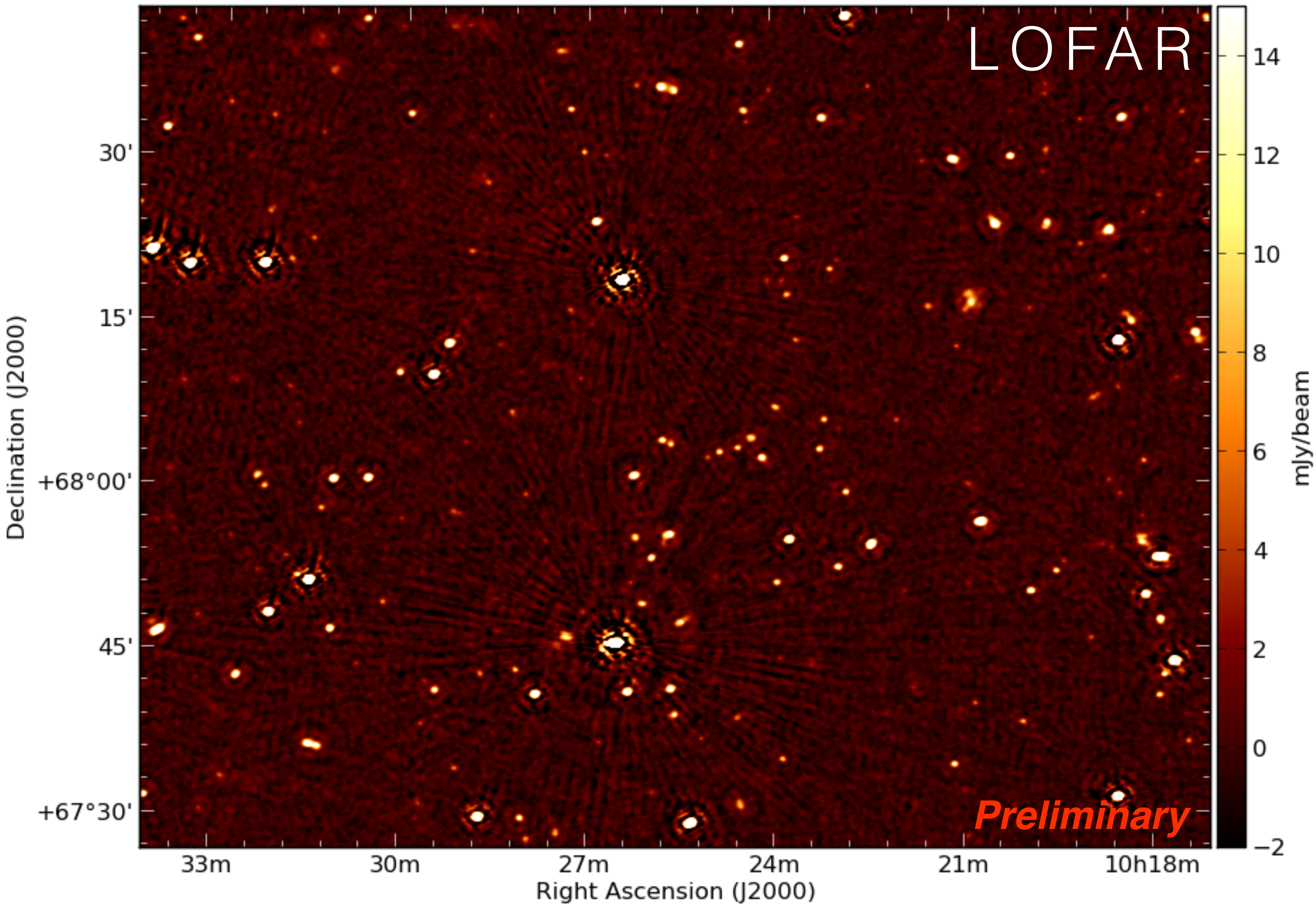
LOFAR:

- σ_{rms} = 300 μJy/beam
- θ = 15x10 arcsec
- ~40+ deg^2

Example area:

- 75x100 arcmin
- Resolution 20 arcsec


GMRT
30'
15'
+68°00'
45'
+67°30'
Declination (J2000)
33m
30m
27m
24m
21m
10h18m
Right Ascension (J2000)
14
12
10
8
6
4
2
0
−2
mJy/beam


LOFAR
Preliminary
30'
15'
+68°00'
45'
+67°30'
Declination (J2000)
33m
30m
27m
24m
21m
10h18m
Right Ascension (J2000)
14
12
10
8
6
4
2
0
−2
mJy/beam

CATALOG & SOURCE COUNTS

GMRT:

- PyBDSM
  - 5σ threshold
  - ~3050 sources
- Full flux density range:
  - 170 μJy to 1.6 Jy
- 14 log-spaced bins
  - Optimised for $N_{\mathrm{bin}} \geq 9$
- 95% complete at $S \geq 1.25$ mJy

LOFAR:

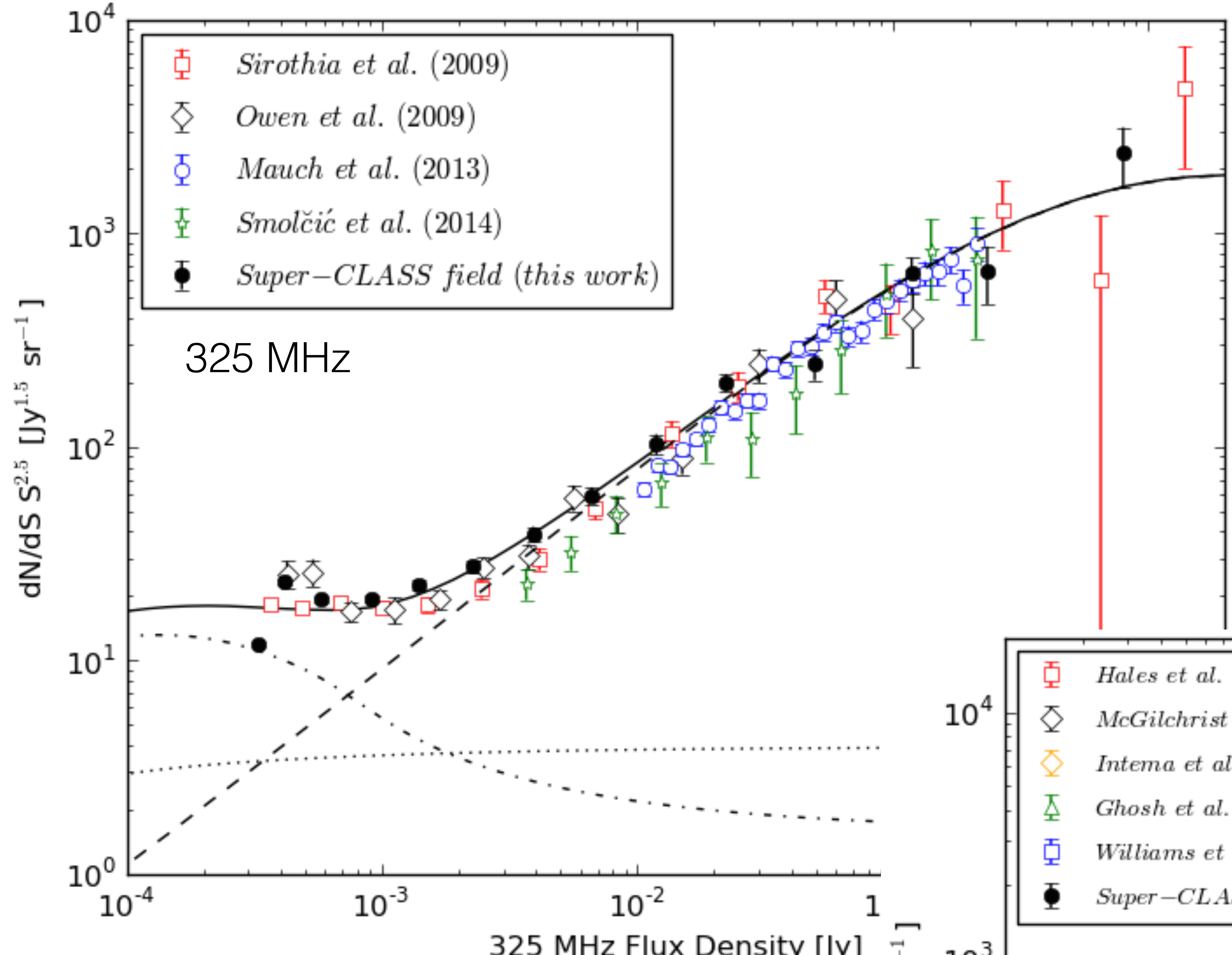
- Masked using GMRT survey area for direct comparison
- PyBDSM
  - 8σ threshold
  - ~550 sources
- Full flux density range:
  - 1.8 mJy to 2.5 Jy
- 8 log-spaced bins
  - Optimised for $N_{\mathrm{bin}} \geq 9$
- No completeness correction yet

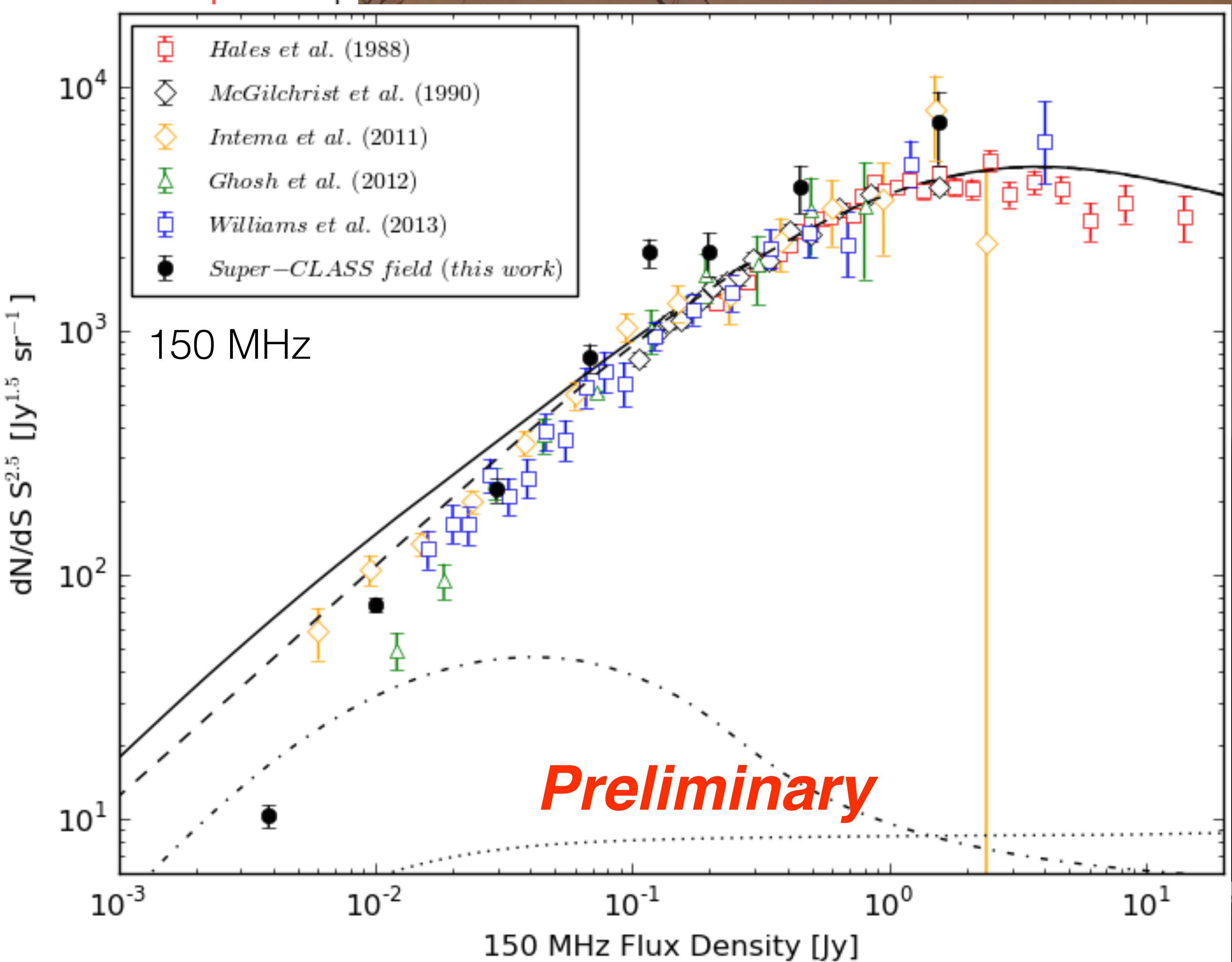
Preliminary

E COUNTS

FAR:

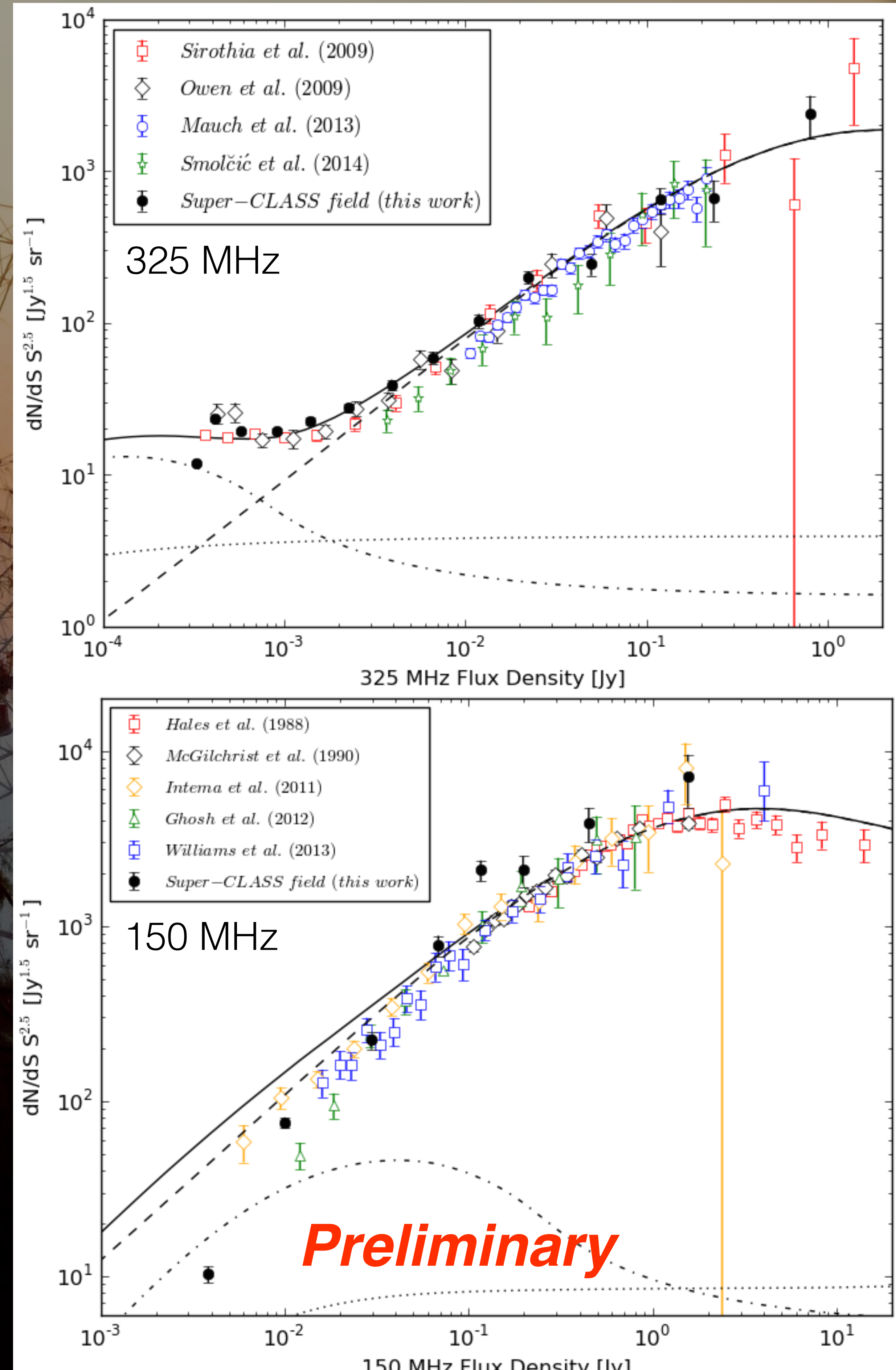
- 14 log-spaced bins
  - Optimised for $N_{\mathrm{bin}} \geq$
- 95% complete at $S \geq$ 1





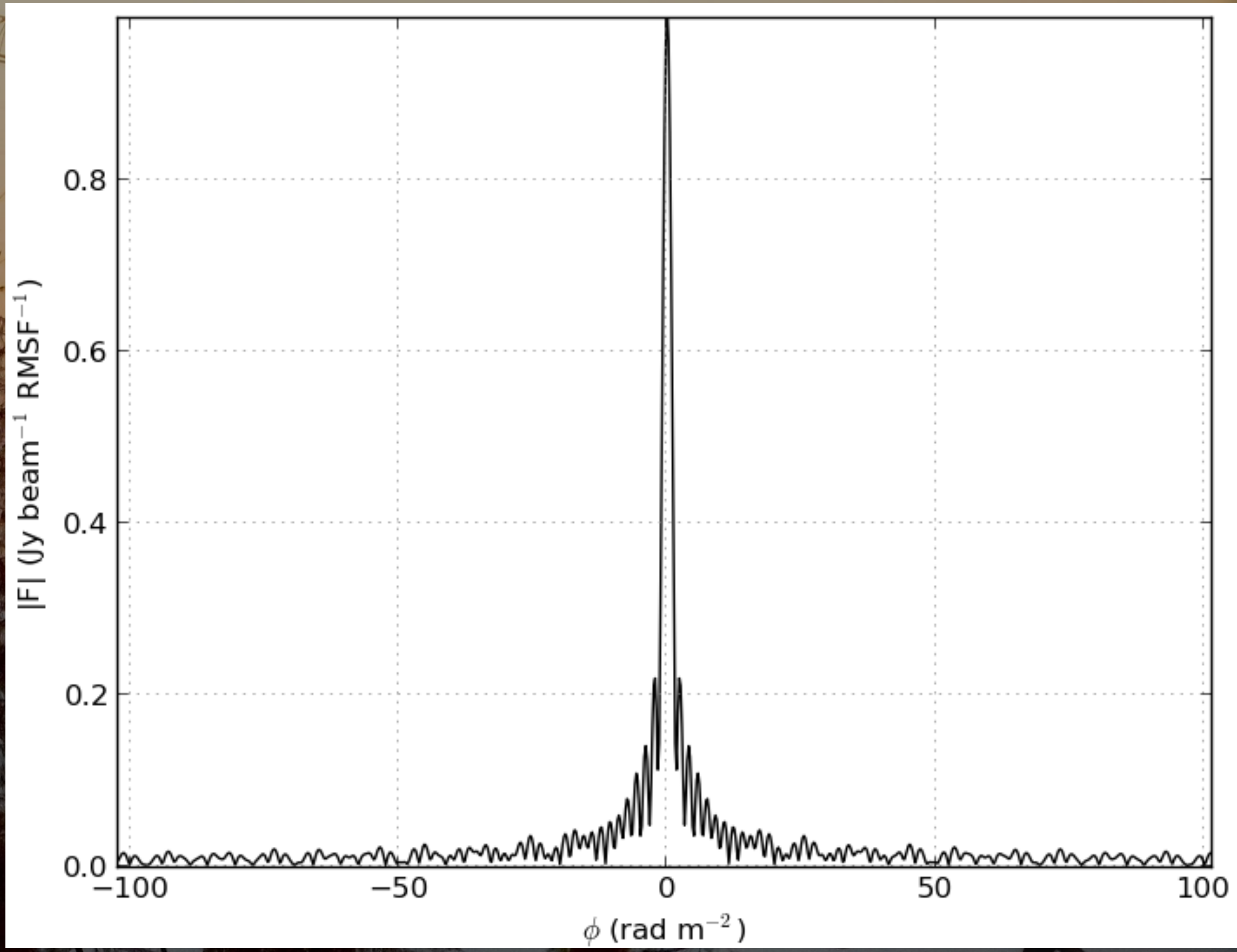
WHAT DO THEY TELL US?

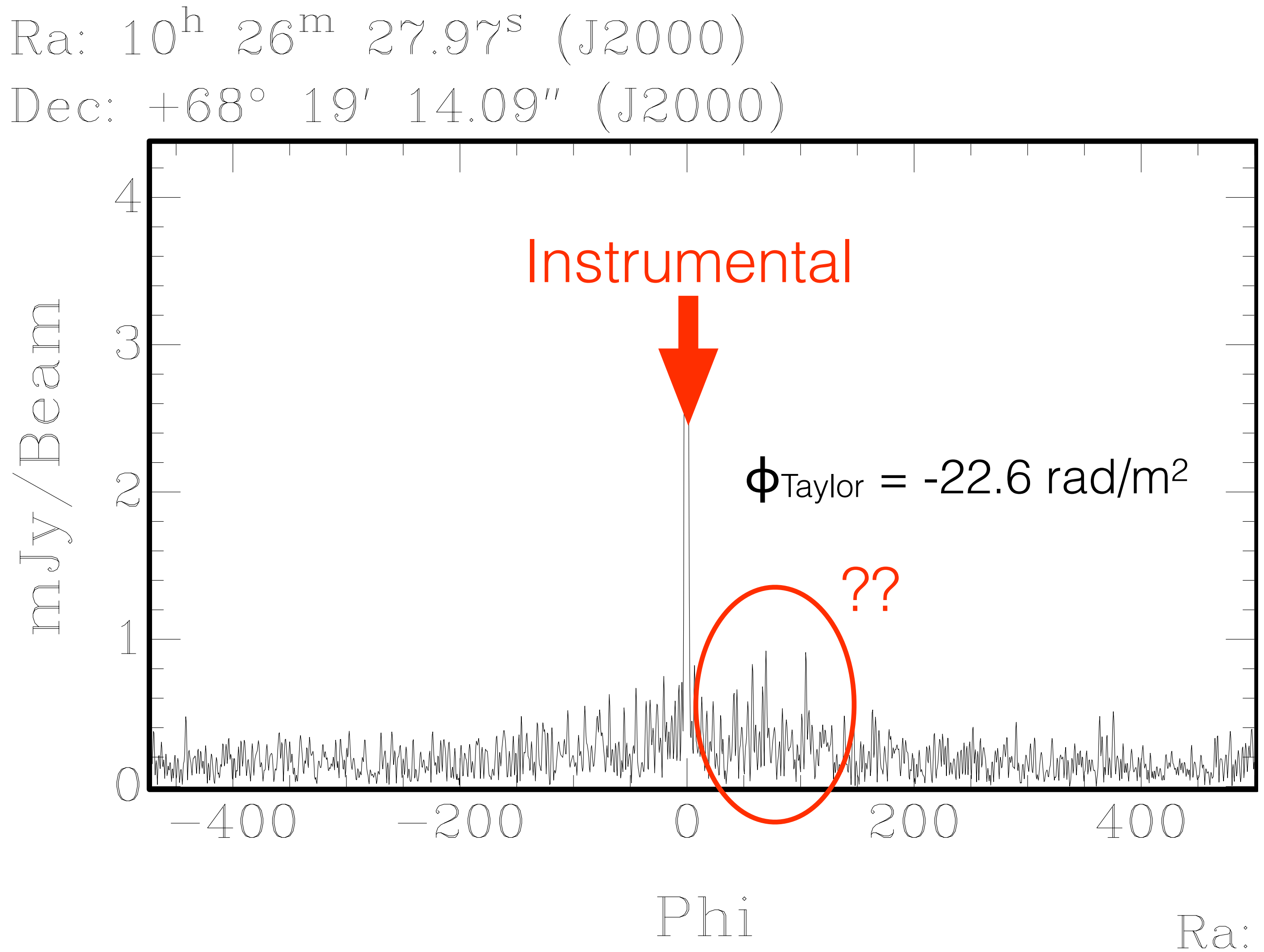
- AGN-type dominated above a few mJy
- Flattens below a few mJy at 325 MHz
- Secondary drop at faintest flux density bin, *S* = 368 μJy at 325 MHz
  - Seen at *S* ≤ 150 μJy at 1.4 GHz (Bondi et al. 2008)
  - Not seen yet at 325 MHz *but* needs sensitivity well below 100 μJy
  - Cosmic variance? Bias?
- No evidence of flattening down to a few mJy at 150 MHz
  - *But* potentially highly incomplete at this flux density



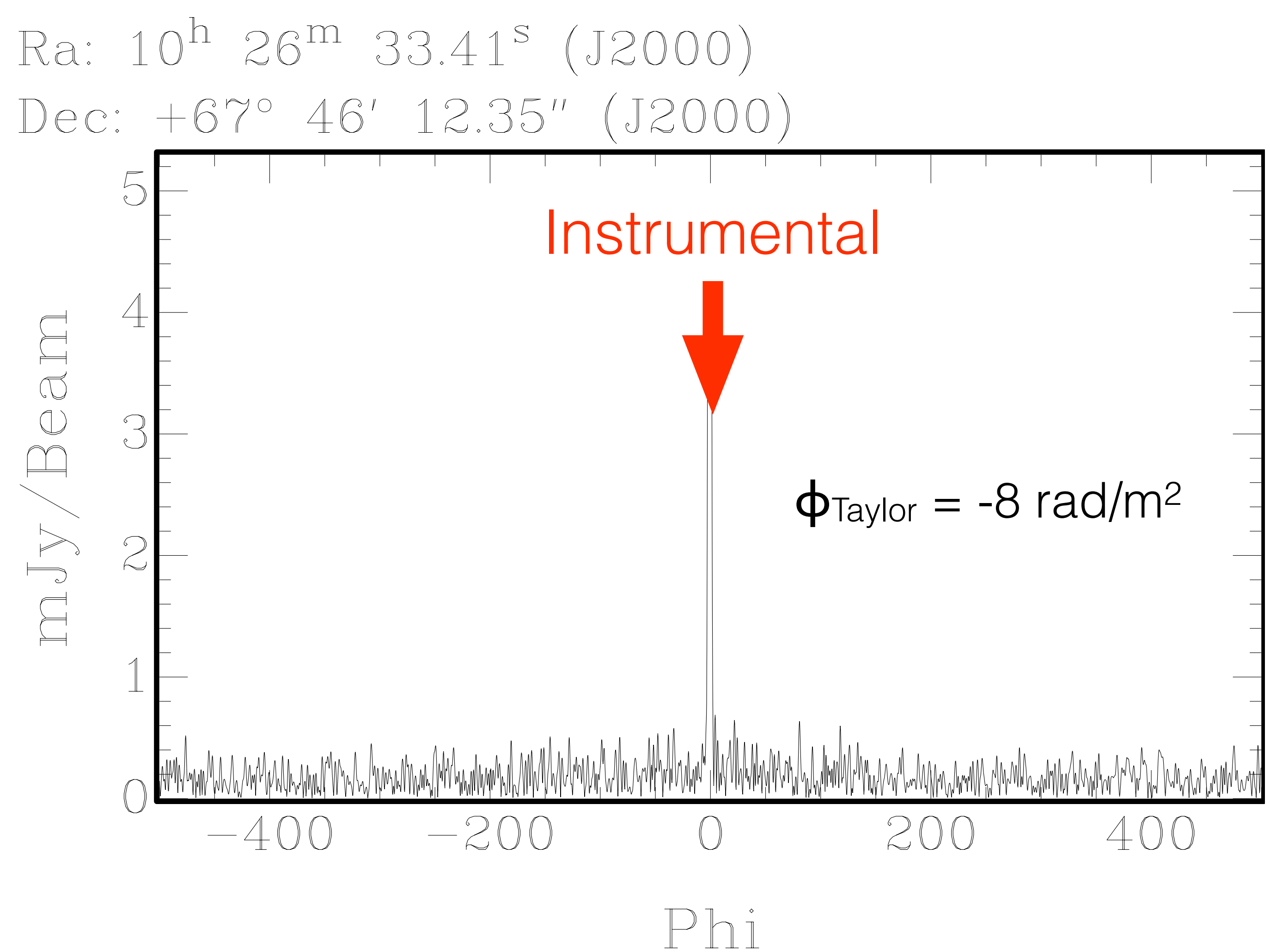
RM SYNTHESIS

- Averaged in frequency:
  - 4 ch/SB or 48.8 kHz
  - 150 SB processed
  - 126 - 156 MHz
- LOFAR frequency coverage gives excellent FD-space resolution
  - $\Delta\phi \simeq 1.8$ rad/m^2
  - $\|\phi max\| \simeq 400$ rad/m^2
- Toward clusters, we might expect RM of 10^3 - 10^4 rad/m^2
- Novel technique for finding sources:
  - Sum over *P* for all channel images => total *P* at each pixel



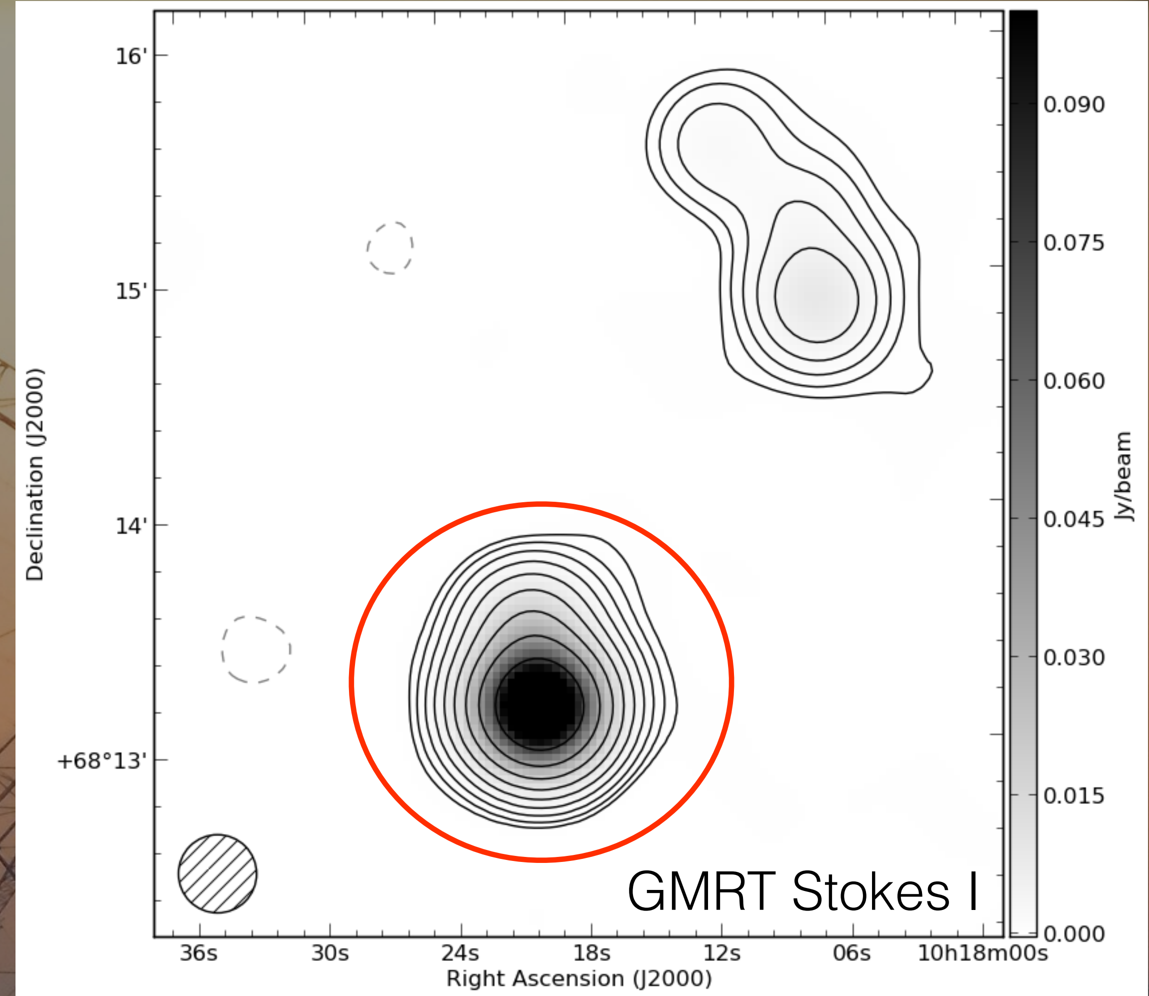


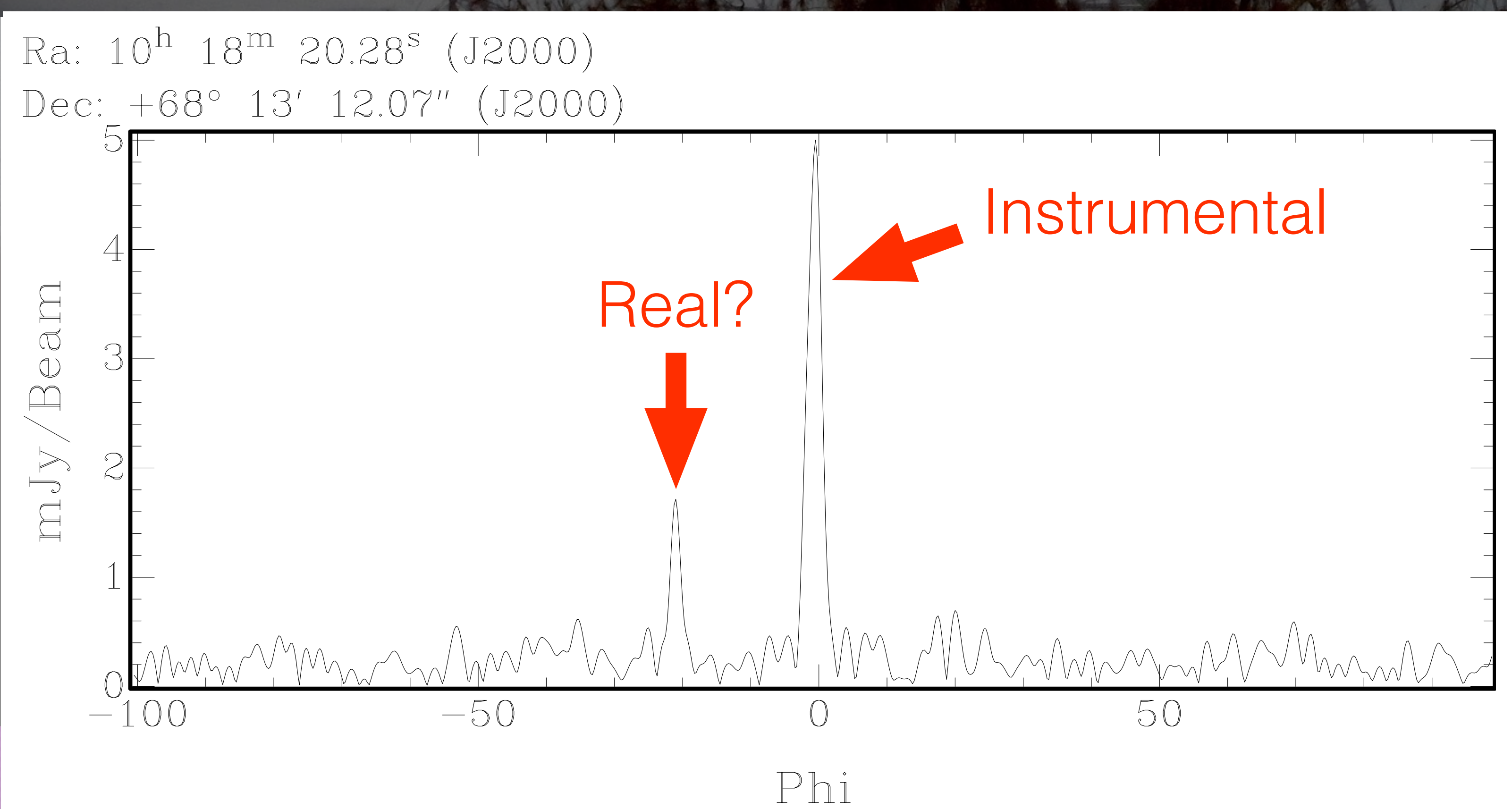
- Taylor et al. (2009) RM catalog
- Seven sources within GMRT field area
  - A few x10 within full LOFAR f.o.v.
- Two within known cluster / supercluster environment

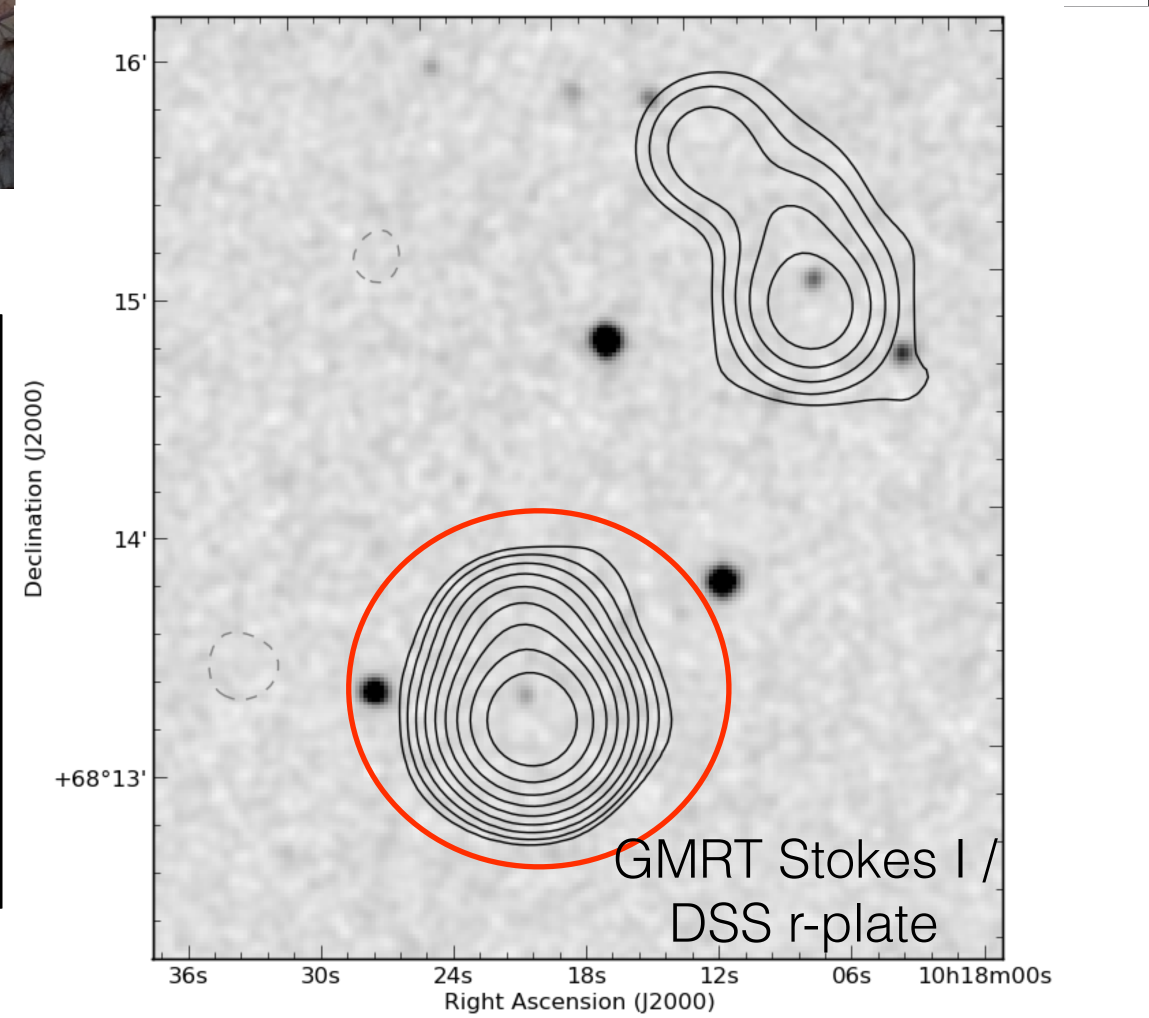


- Strong instrumental polarization
- No significant detection of source polarization from these
  - Hints of peaks in some source RM profiles
  - Highest possible S/N not yet achieved

- Not in Taylor catalog - new source?
  - $\phi = -21.25 \pm 0.60$ rad/m^2
- Peak Stokes P ~ 1.71 mJy/beam
- Oppermann et al. (2012) suggest Galactic RM of -10 rad/m^2
- WISE IR catalog lists this as γ-ray blazar candidate
  - No z measurements (yet…)







CONCLUSIONS

- Deep radio study of galaxy super-cluster field
  - Deepest ever study at 325 MHz
  - Among the deepest at 150 MHz
- Differential source counts consistent with previous work
  - Steep-spectrum sources dominate population above 1 mJy at 325 MHz, sole population recovered at 150 MHz
  - Flattening below 1 mJy at 325 MHz
  - Suggestion of further drop at faintest flux density bin, S = 368 μJy *but* need further studies to confirm
- RM synthesis
  - No detections of emission from sources in Taylor RM catalog
  - Detection of *new* source with RM = -11.25 rad/m^2 (corrected for Galactic rotation)

THANK YOU FOR LISTENING.

QUESTIONS?