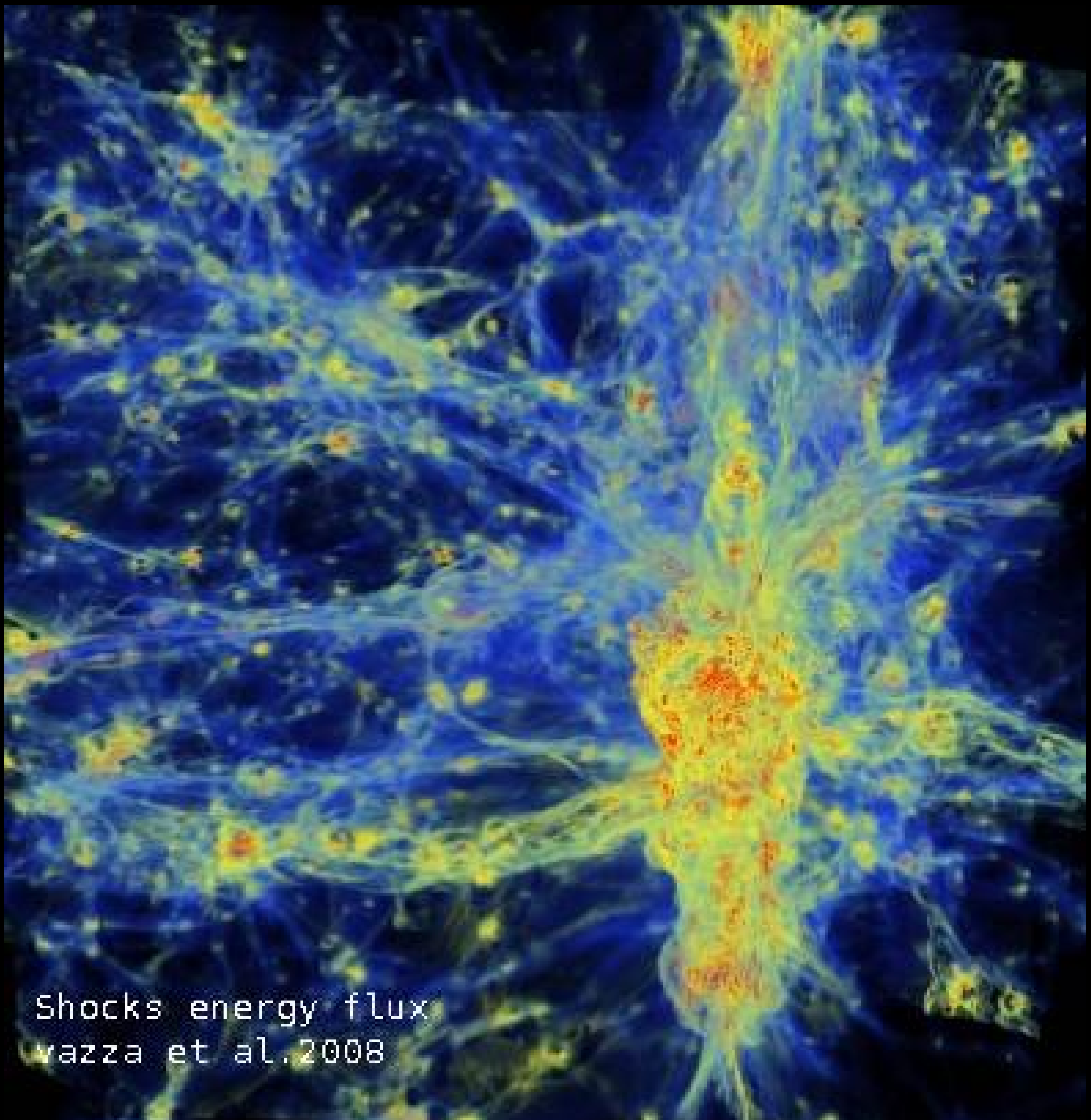
Forecasts of radio emission from the Cosmic Web



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P.Wang (Nvidia)

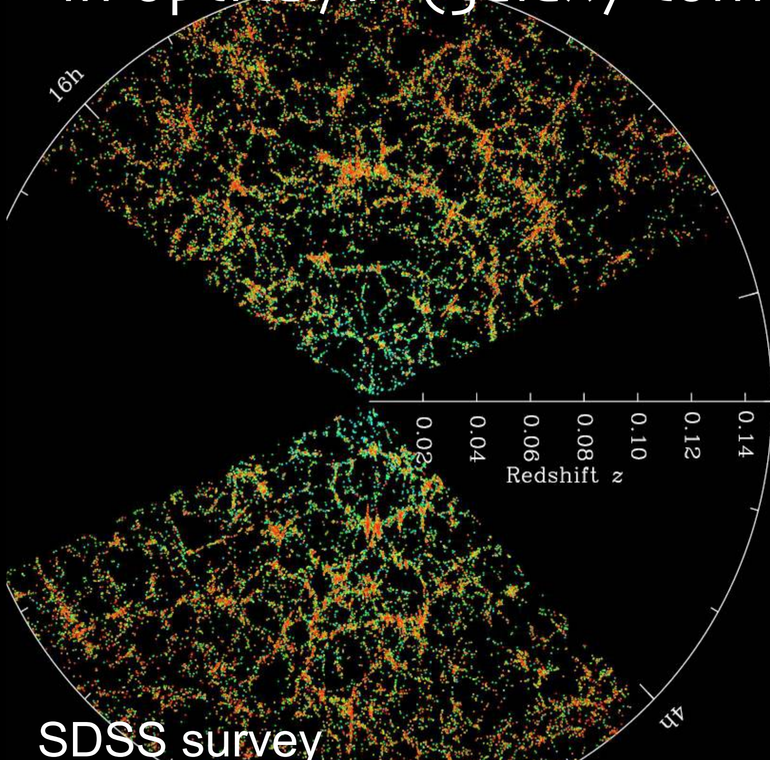
+ SKA-LOW "Tiger Team"

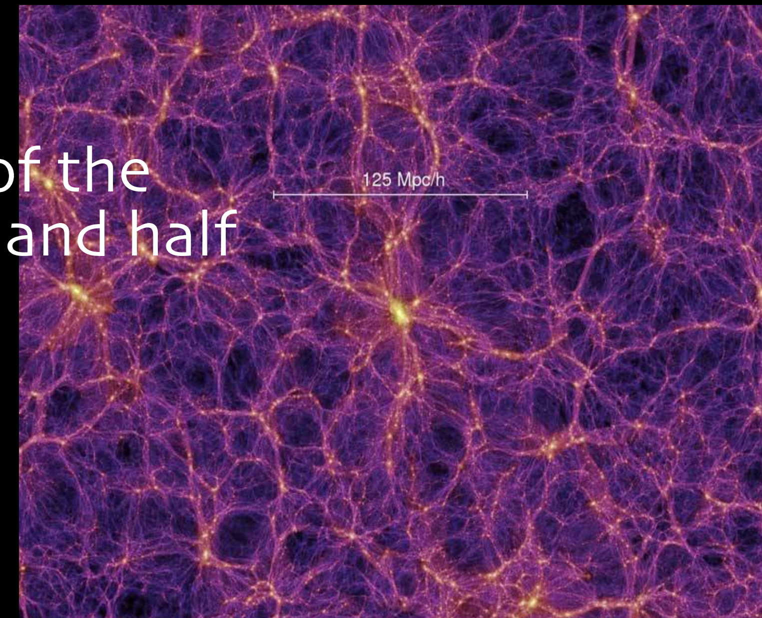
Paris, 13.02.14

Scientific case:

- About 90% of the total (gas+DM) mass of the Universe is contained in the Cosmic Web, and half of this in filaments

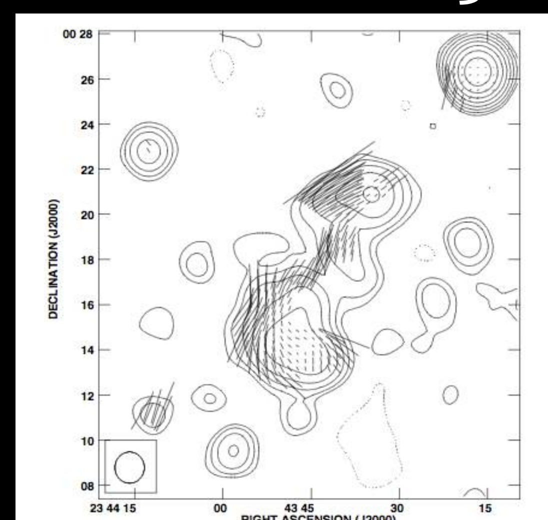
- Yet, the CW has been clearly imaged only in optical/IR (galaxy components)



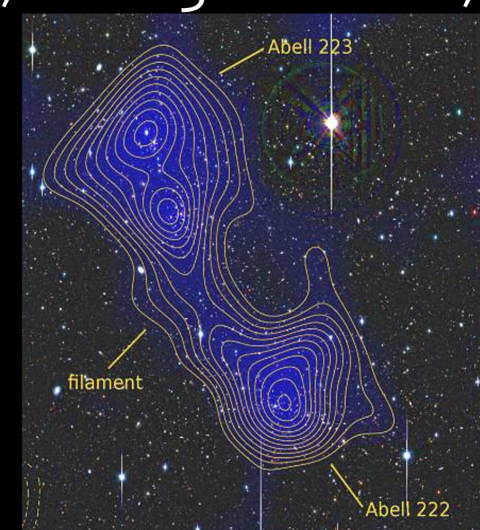


Millennium Run Springel+05

- The detection of the diffuse gas components is still elusive at all wavelenghts, owing to low n, T



Zwcl+2341.1+0000, Giovannini+12
See also Bagchi+, Vanweeren+



SZ effect in intercluster Filament(?)
The Planck Collab.13

GAS TEMPERATURE

MAGNETIC FIELD

GRAVITY PULL

SHOCKS → RELATIVISTIC ELECTRONS/PROTONS

TURBULENCE → MAGNETIC FIELD AMPLIFICATION

UNKNOWNS (at the scale of filaments):

PARTICLE ACCELERATION:

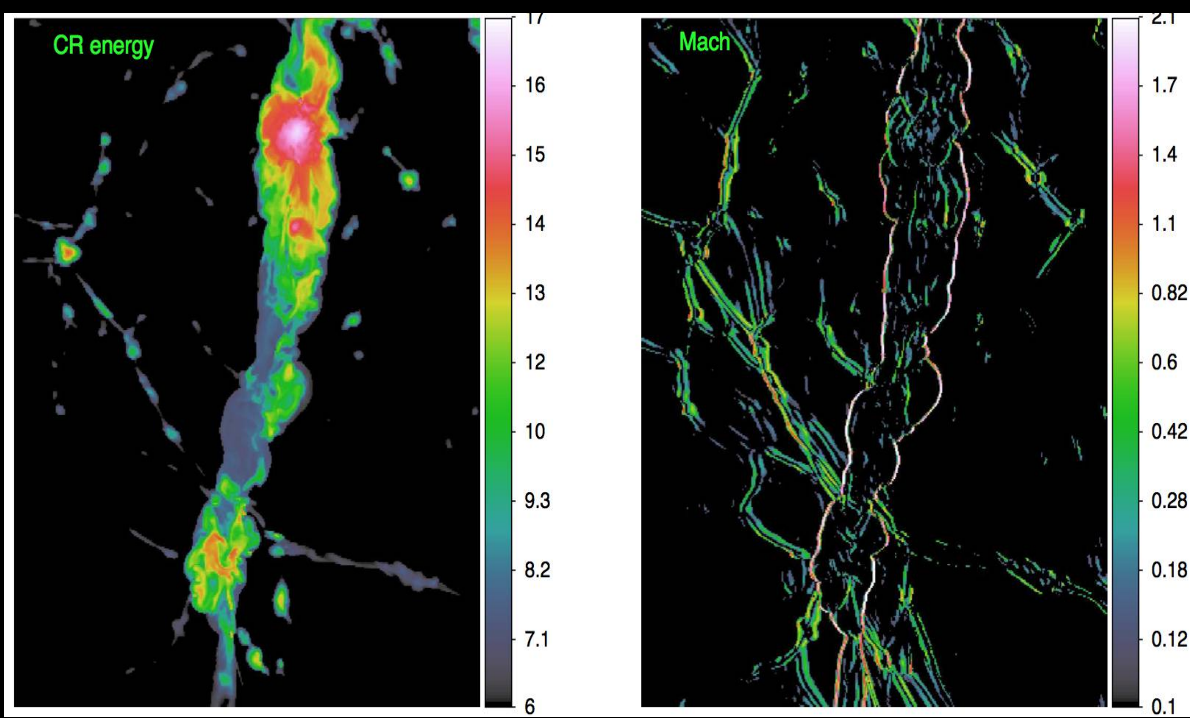
What is the efficiency?

- Upper limits from clusters (-ray: FERMI)
- Diffusive shock acceleration (FERMI I) theory, calibrated with Supernovae
- <0.1-10% of conversion from shock kinetic energy
- It can be simulated with 2-fluid model.

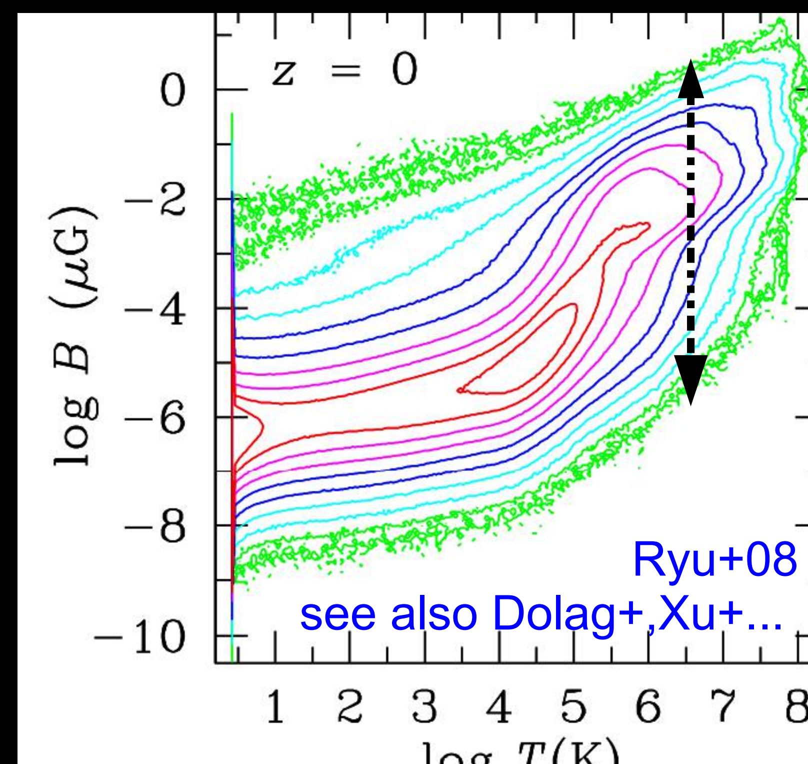
MAGNETIC FIELDS:

What is the "seed" field? Dynamo efficiency?

- Loose constraints $10^{-9}\mu G < B < 1\ \mu G$
- Difficult to simulate: "simple physics" but high resolution needed.

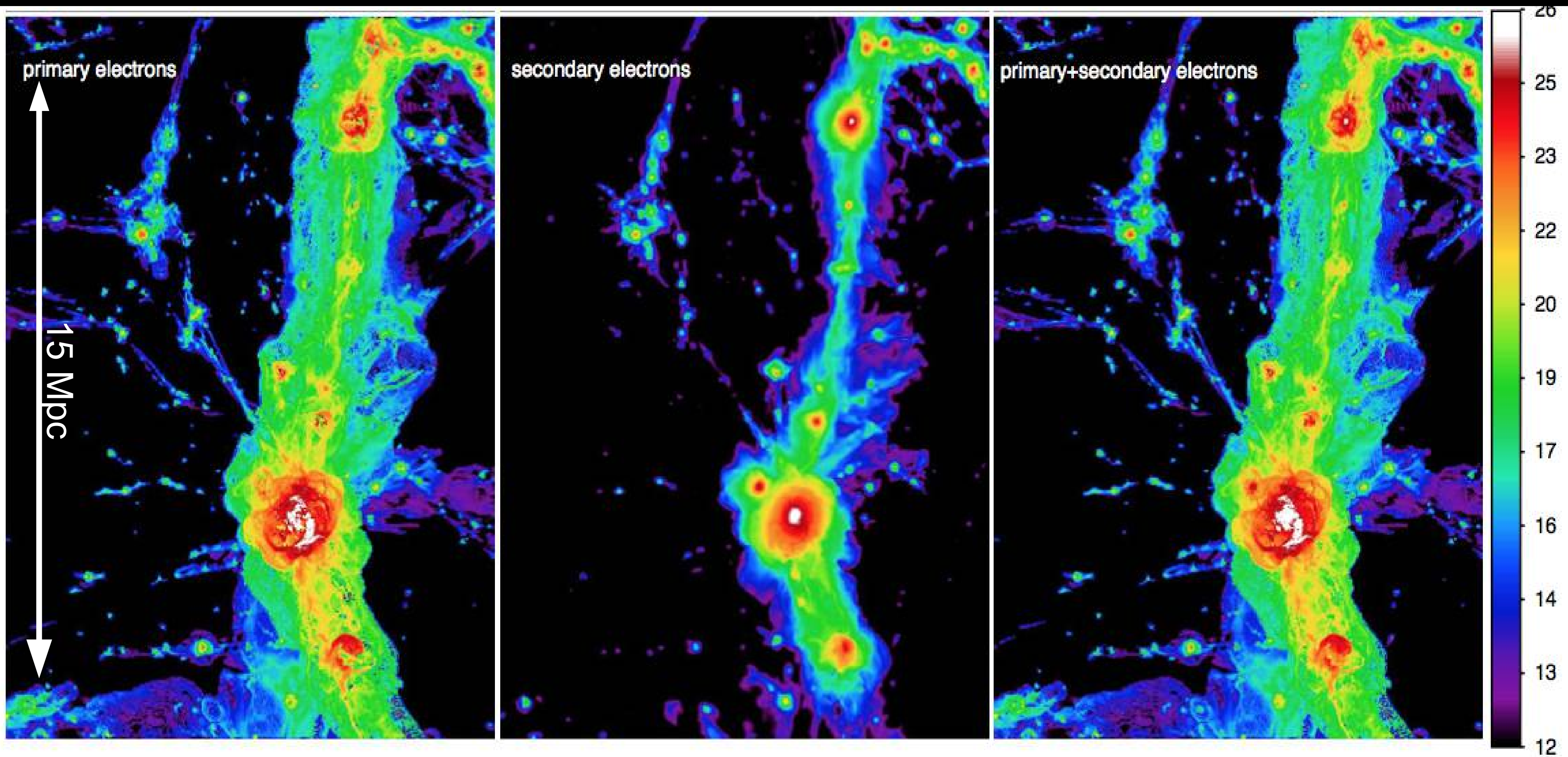


FV+12,13,14... see also Minati+,Pfrommer+



Can we observe filaments with the next generation of radio arrays? (FV,Ferrari,Brüggen,Bonafede...)

- Electrons accelerated at shocks (0.01% $_{\kappa\nu}$) and injected by hadronic collisions (n^2) → simulated self-consistently with ENZO+
- Magnetic field → attached in post-processing



LOFAR LBA (60 Mhz):

- *The largest (10 Mpc) filaments can be entirely detected if $B > 0.5 \quad \Gamma$*

No spectacular detection (so far)

→ the diffuse field should be $B \leq 0.2 \quad \Gamma$

WHAT WILL SKA SEE?

- Simulated volumes from our 2048^3 simulations from FV, Gheller & Brüggen 2014 (among the most resolved so far)
- Simulation of baseline sampling as a function of z, thermal and confusion noise threshold, cosmological dimming
- Detectability : > 3 (confusion/thermal) for SKA LOW – MID - SUR

(based on SKA1-Imaging Science Performance by R.Braun)

Detected emission >3rms noise/confusion

B=0.1 μG

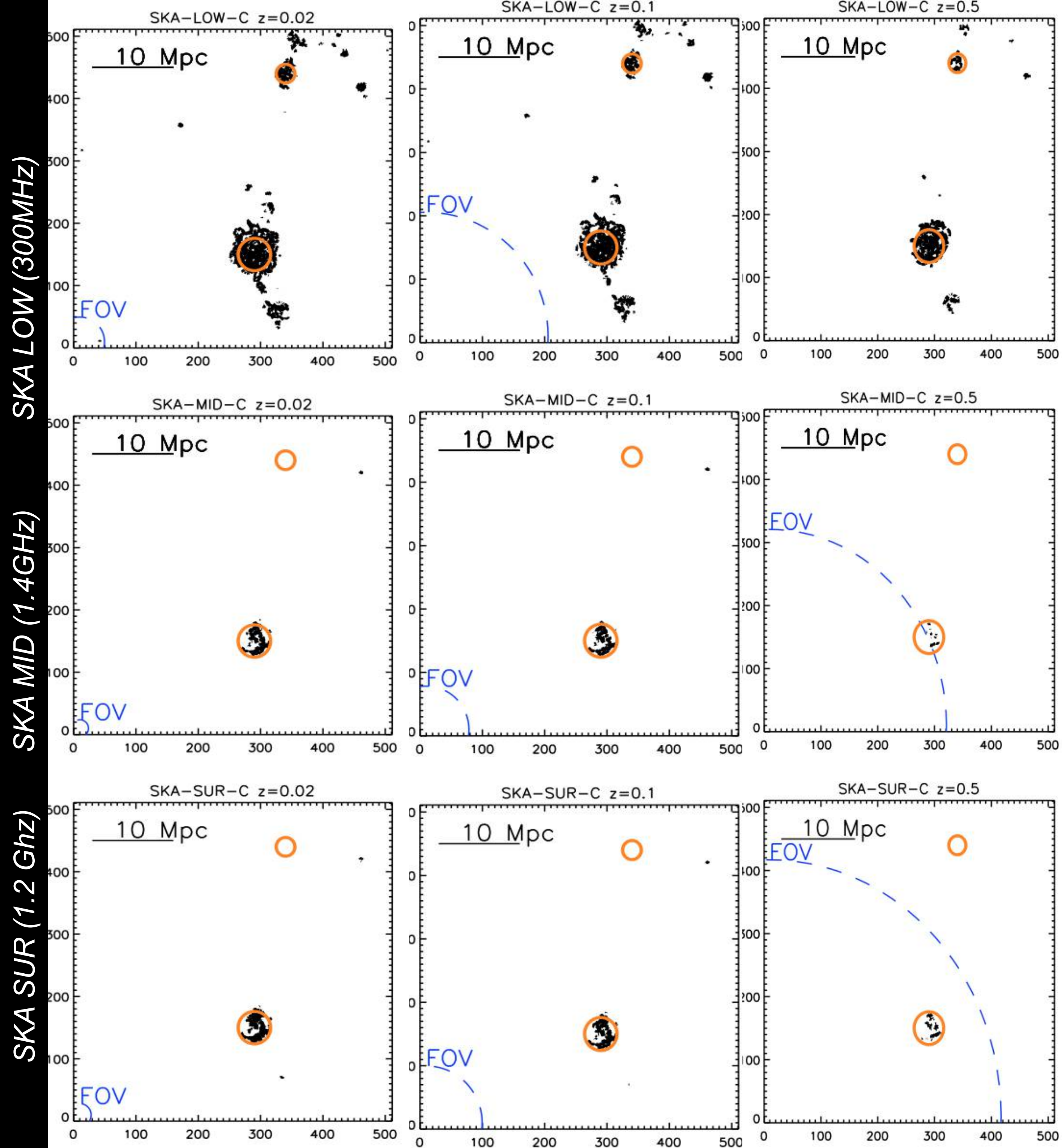
Different redshifts

<u>SKA-LOW :</u>

- Emission detectable ouside the virial radius of nearby clusters, down to z=0.1
  → confusion limit

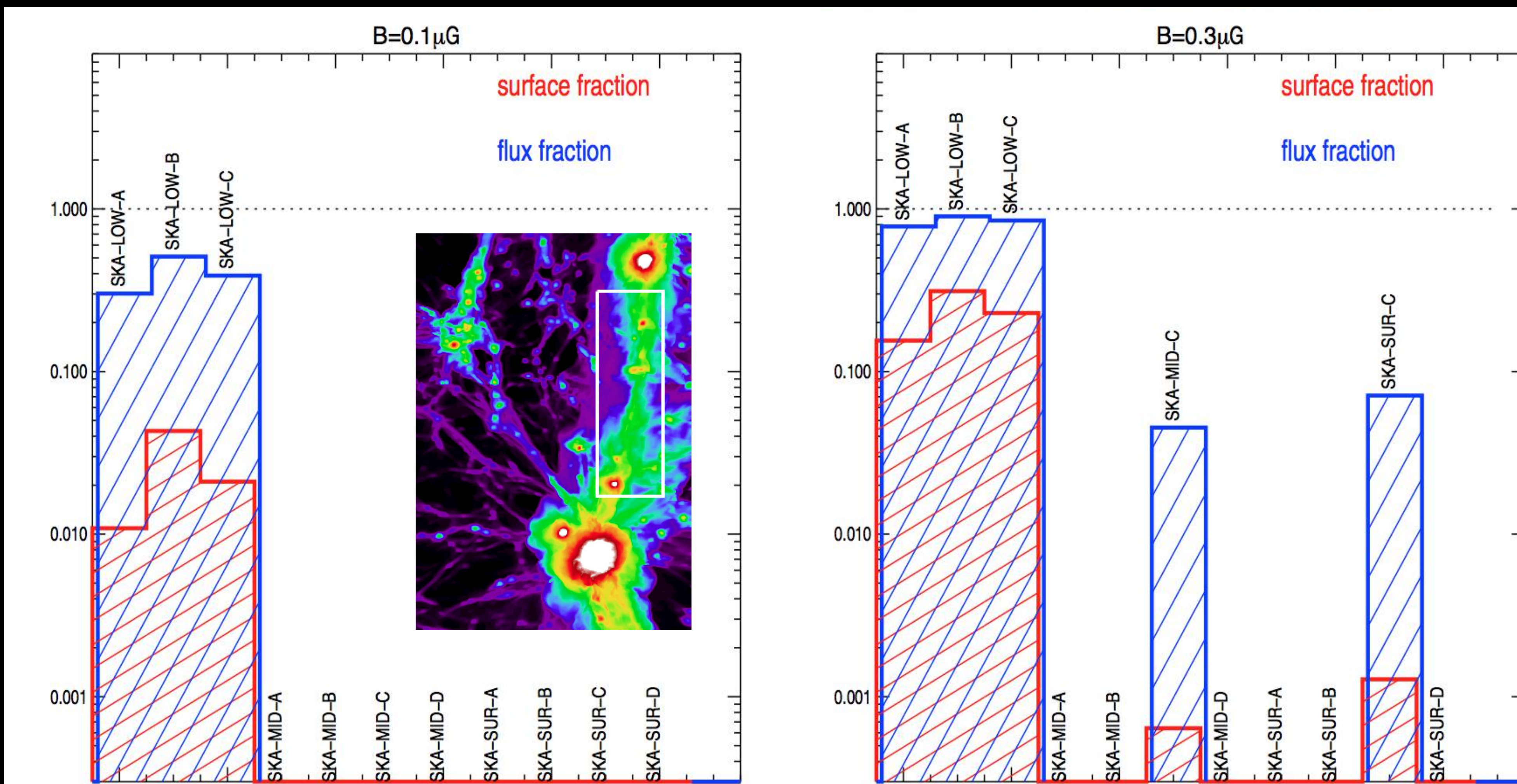
<u>SKA-MID/SUR:</u>

- <u>NO</u> emission can be detected outside of the virial radius of clusters.
  → missing baselines



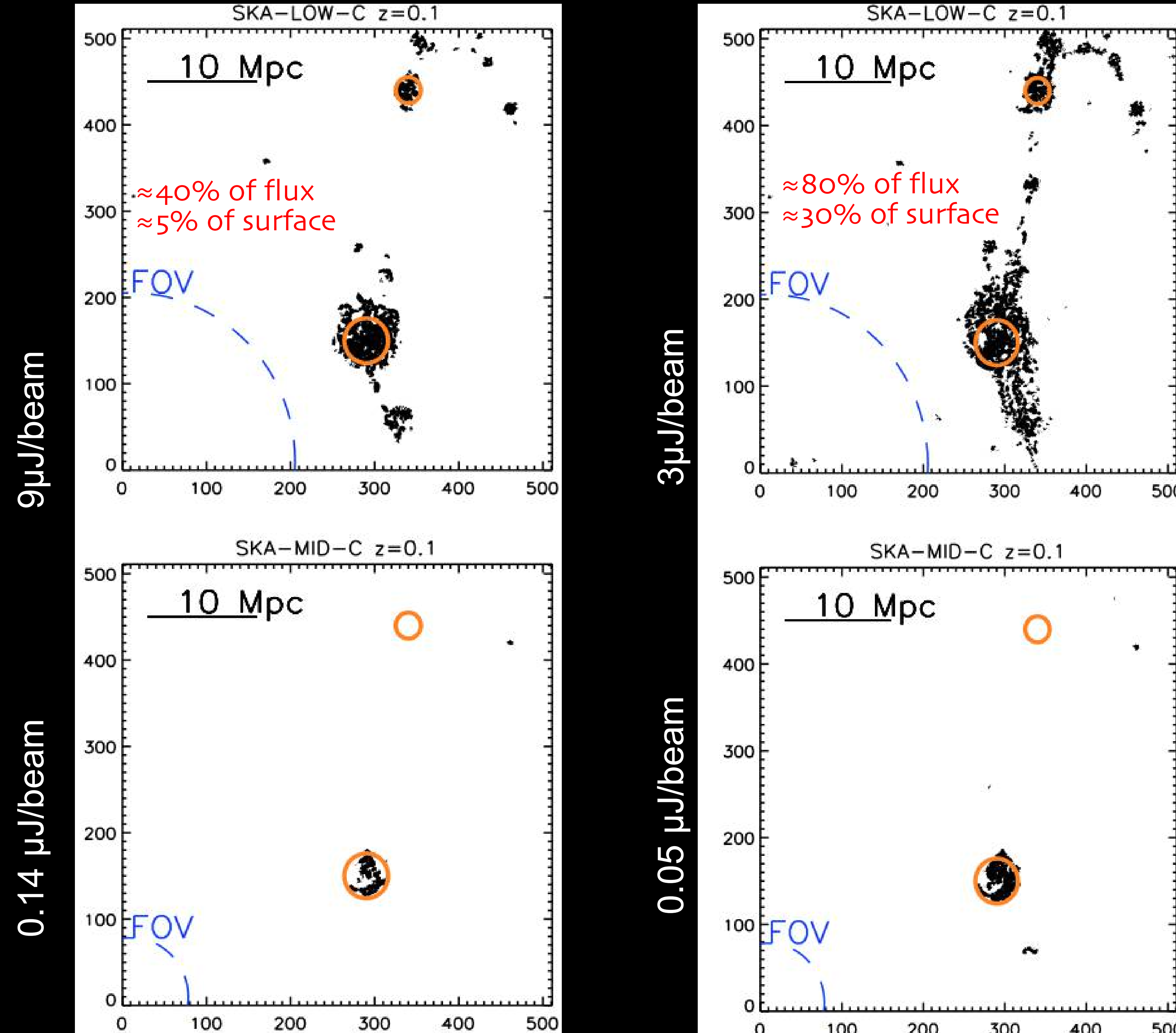
HOW MUCH FLUX / SURFACE FROM THE FILAMENT CAN WE DETECT?

array	configuration/strategy	frequency $[MHz]$	beam size [arcsec]	field of view [degrees^2]	min. baseline [m]	sensitivity 1 [μJy/beam]	sensitivity 2 [μJy/arcsec^2]
SKA-LOW-A	full.res+conf.	110	6	8	45	5.5	0.134
SKA-LOW-B	full res+conf,1000 hr	300	3	8	45	0.5	0.490
SKA-LOW-C	full res+conf., survey	300	10	8	45	9	0.794
SKA-MID-A	1000hr	1400	0.5	0.49	15	0.09	0.317
SKA-MID-B	2 years	1400	0.5	0.49	15	5.8	20.475
SKA-MID-C	1000 hr+tapering	1400	10	0.49	15	0.14	0.001
SKA-MID-D	2 years+tapering	1400	10	0.49	15	8.8	0.077
SKA-SUR-A	1000hr	1200	1.0	18	15	0.4	0.353
SKA-SUR-B	2years	1200	1.0	18	15	3.8	3.353
SKA-SUR-C	1000hr+tapering	1200	10	18	15	0.5	0.004
SKA-SUR-D	2years+tapering	1200	10	18	15	4.9	0.043

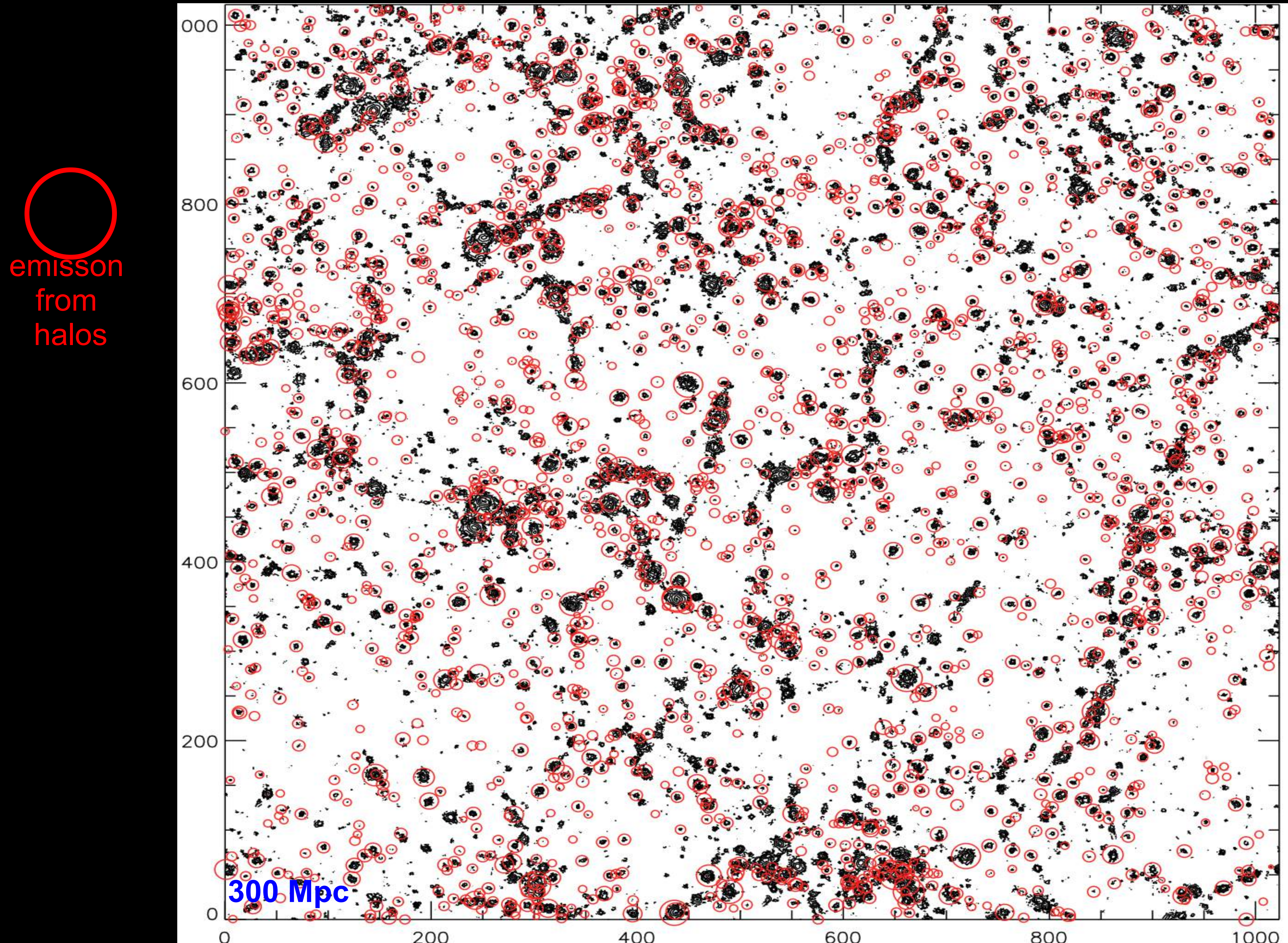


PLANNED ARRAY SENSITIVITY IMPROVED by x3

1000 hr exposures



Larger volumes/statistics can enhance the detection of rare objects



Conclusions:

The detection of cosmic filaments with the existing (LOFAR) and incoming (SKA) radio could be within reach

Any detection/non-detection will inform us about the seeding and amplification process of large-scale magnetic fields.

→ SKA-LOW has best chances of detecting filaments for $z<0.1$

→ "beating confusion" in SKA-LOW could lead to dramatically enhanced detection of filaments

→ SKA-MID and SUR are not very well suited for this science case, because of missing baselines

FV,Gheller,Bruggen+14

Thanks