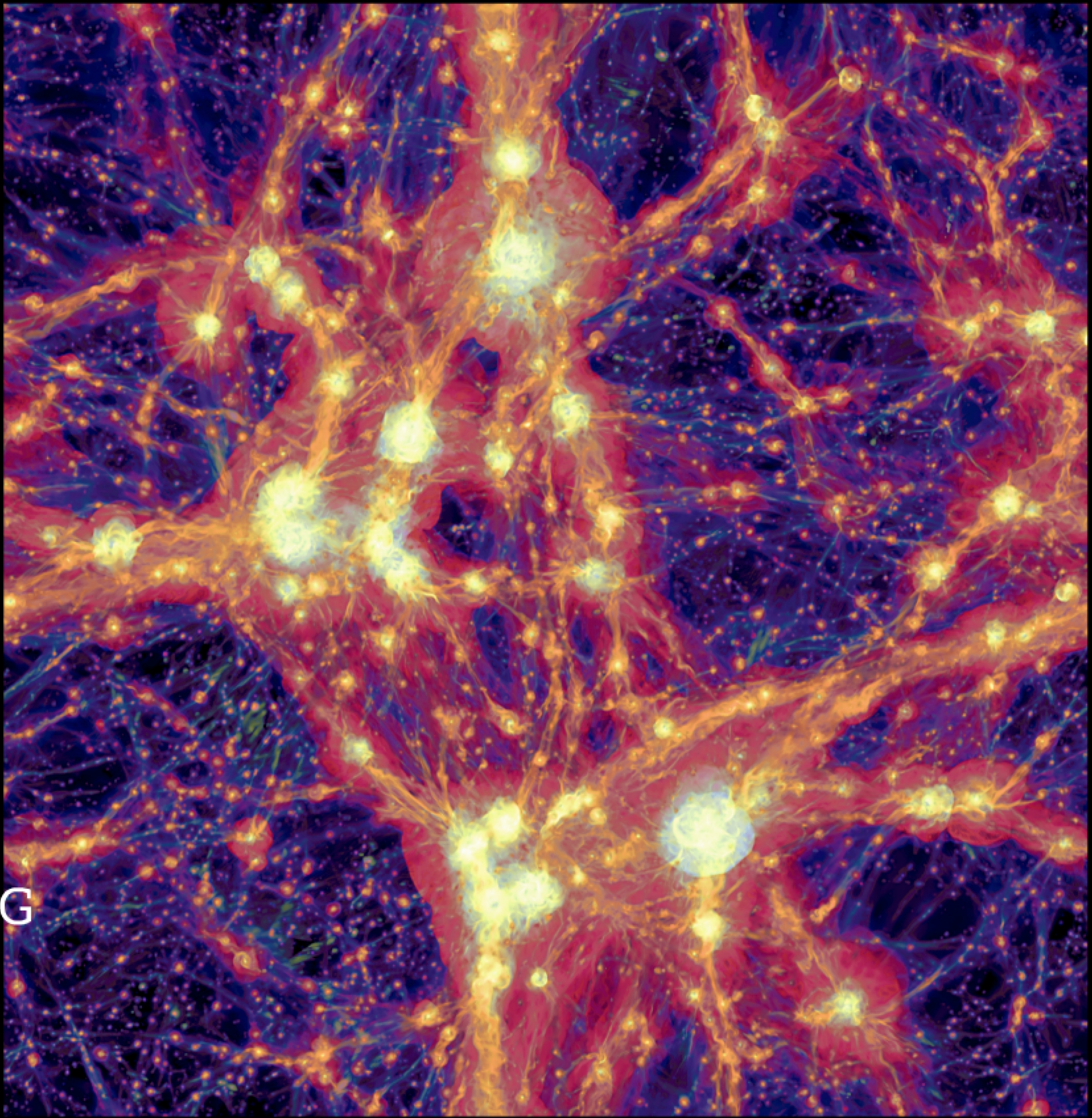
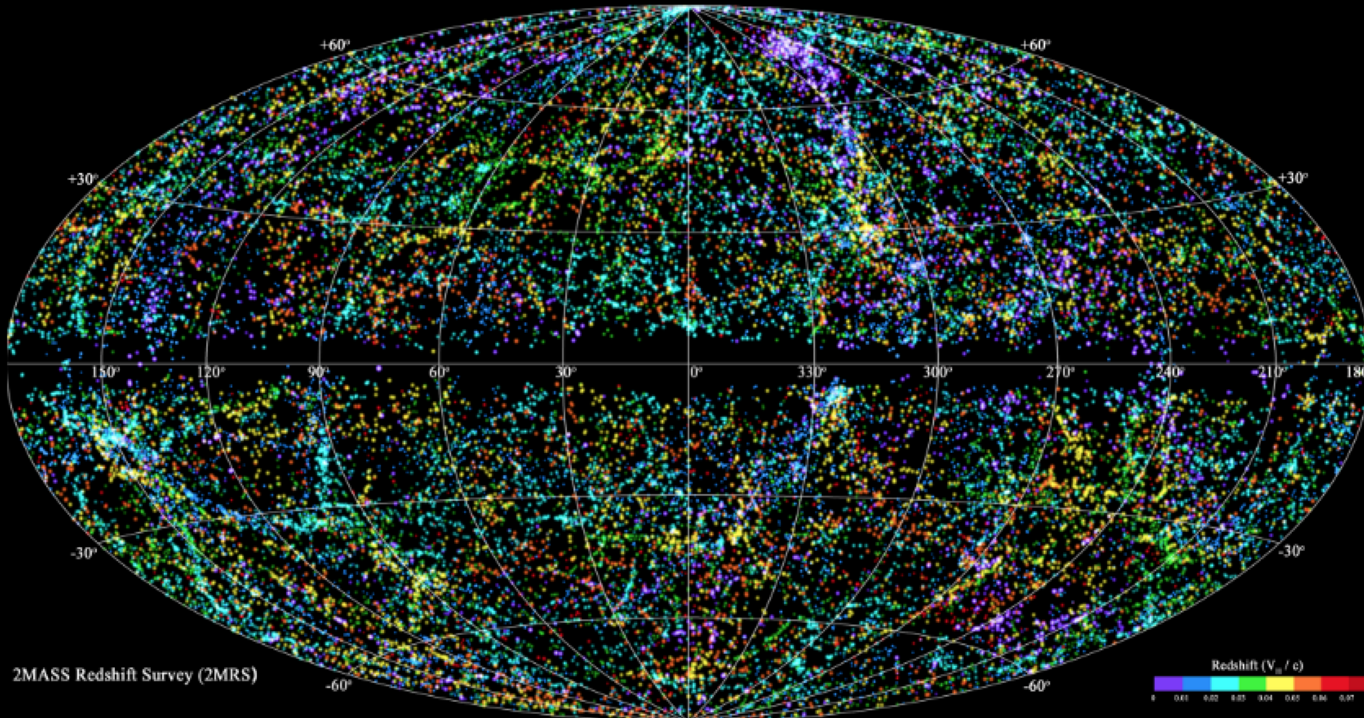
The cosmic web in existing and future radio surveys

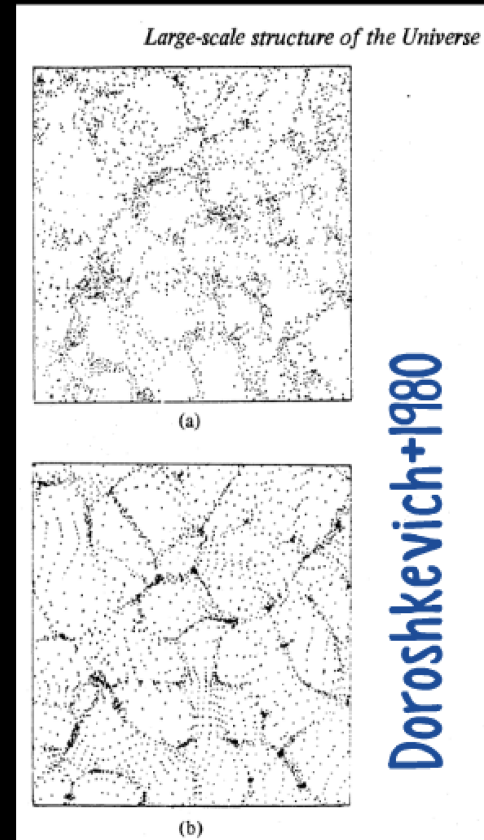


F.Vazza
+C. Ferrari
+A. Bonafede
+M. Bruggen
+C. Gheller
+S. Brown
+R. Braun
+ENZO collab.
+SKA Continuum WG

"The many facets of extragalactic radio surveys" - Bologna, 20-23 October 2015

THE COSMIC WEB





Doroshkevich+1980

- first discovered by N-body simulations! (late 70's)

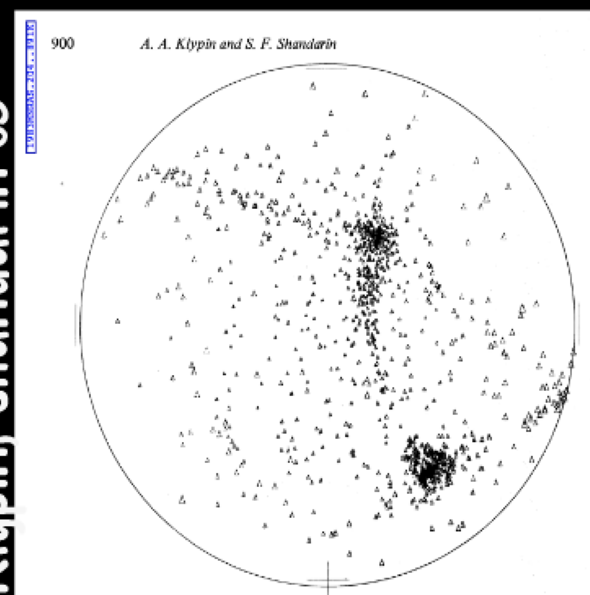
~ 90% of baryons are in the cosmic web

~ 50% of baryons are in filaments

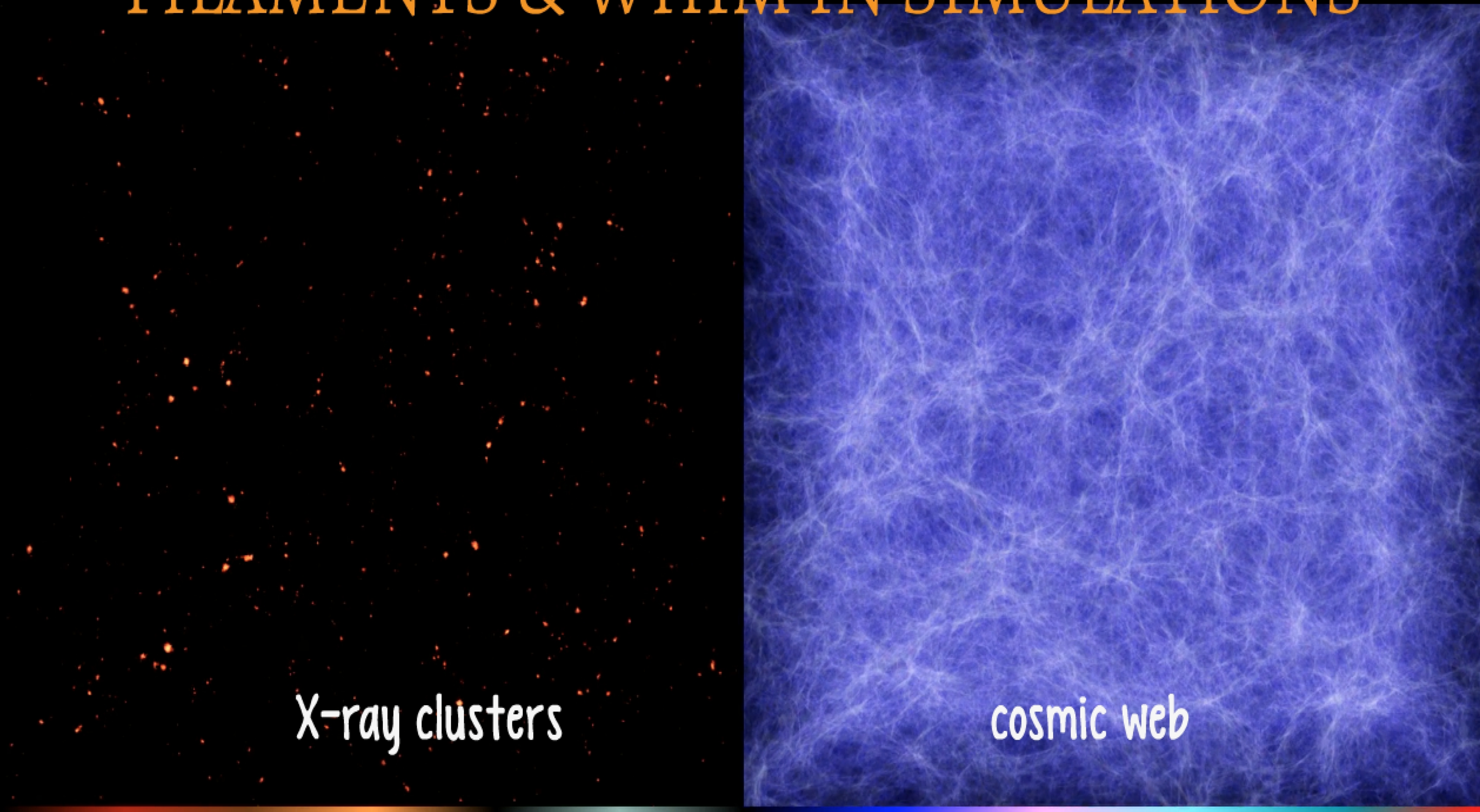
evidence from Lyman-alfa, X-ray.. but NO images

...basically all gas (WHIM) there remains invisible.

Klupin, Shandarin 83



FILAMENTS & WHIM IN SIMULATIONS



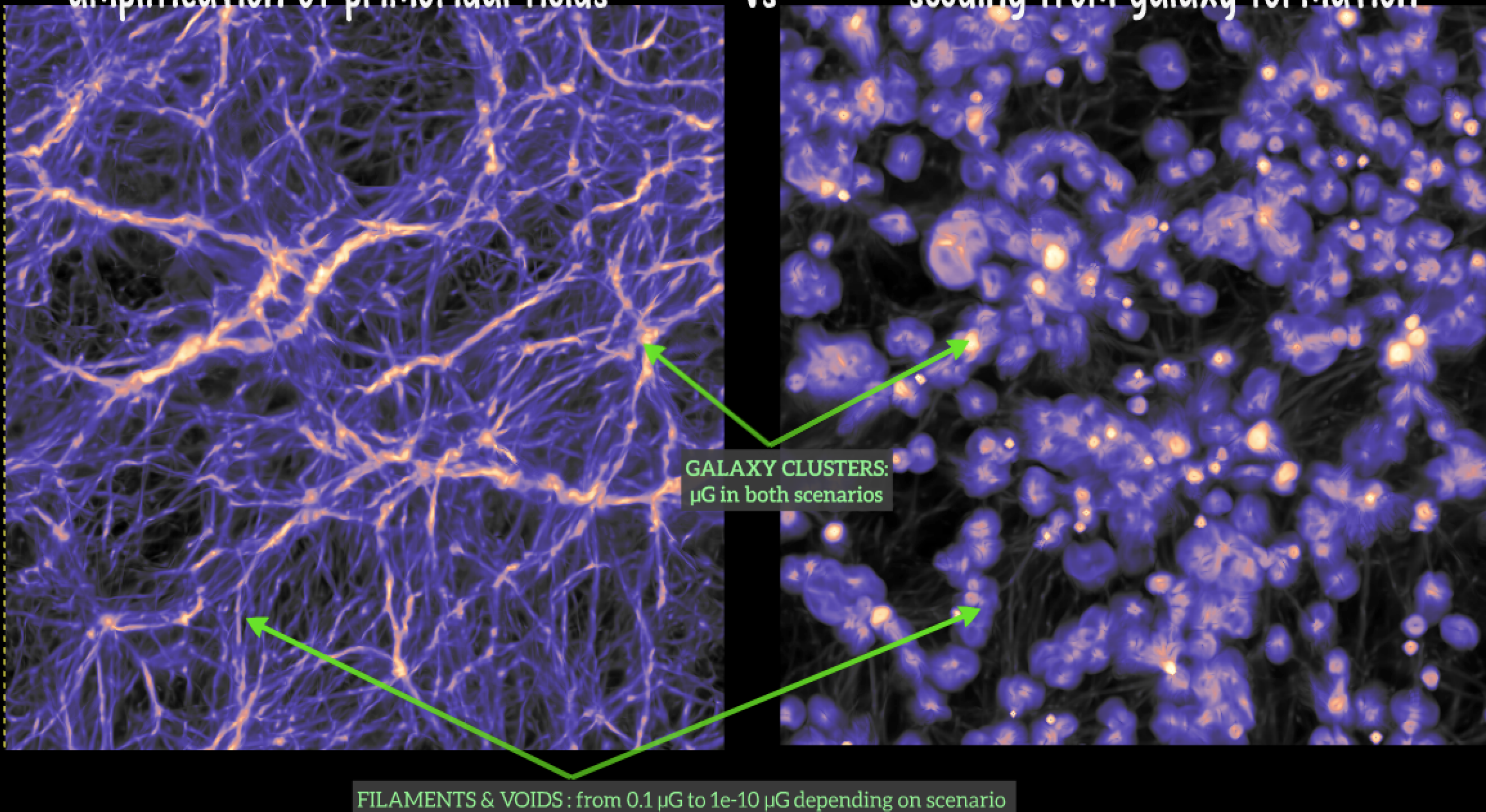
in (100 Mpc)^3 :

~ 1000 filaments of which ~ 1 with M=1e15 Msol and L>50 Mpc (Gheller,FV+2015)

WHIM properties depend on physical details (cooling, feedback)

EXTRAGALACTIC MAGNETIC FIELDS: A PUZZLE

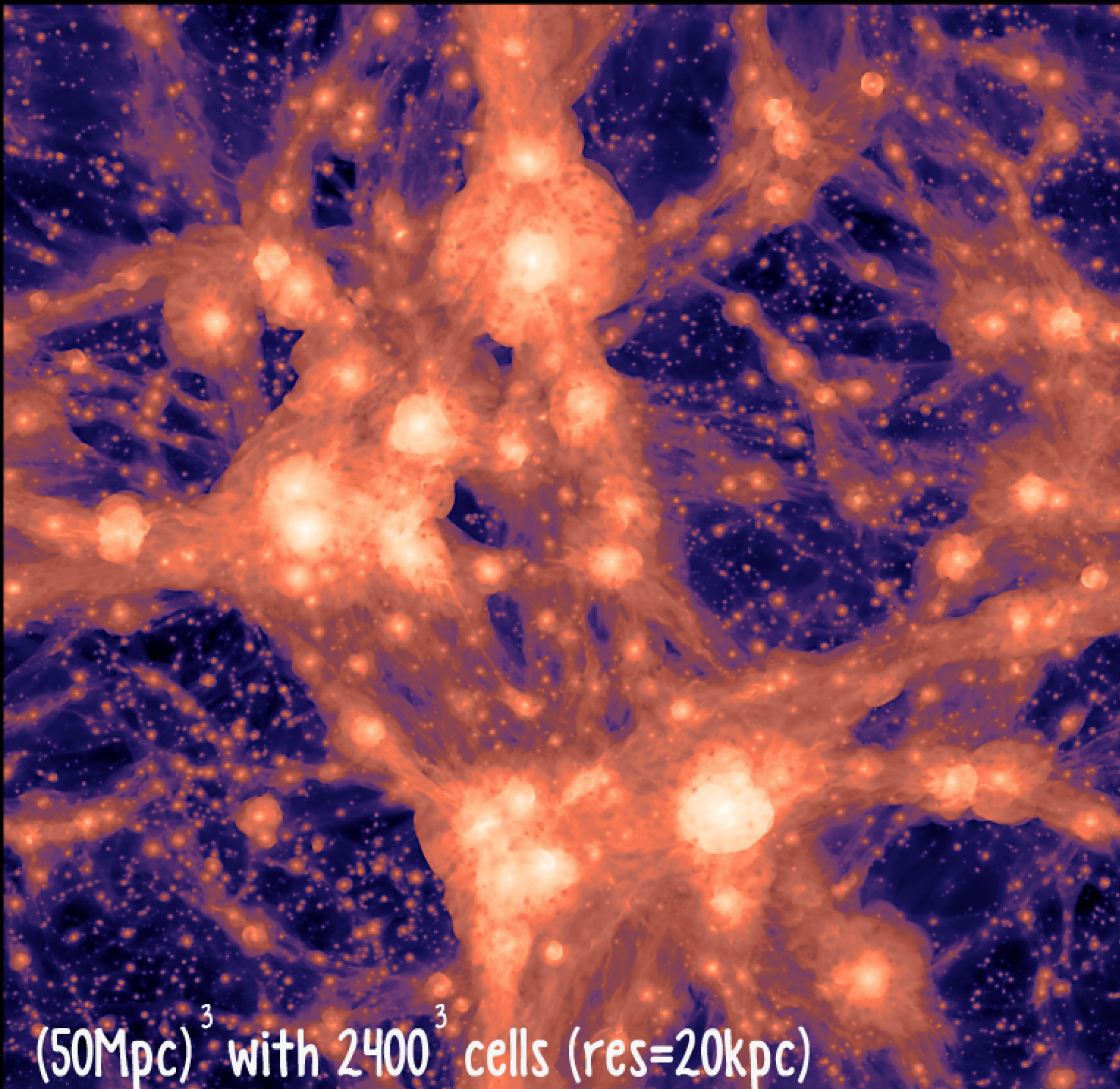
amplification of primordial fields vs seeding from galaxy formation



from different magnetisation histories we predict VERY DIFFERENT magnetic fields for the cosmic web (see also Dolag+06, Donnert+09, Xu+09...)

Can we detect the magnetised/shocked cosmic web?

(FV+15 SKA White Book, FV+15 A&A)



CHRONOS suite of simulations
-grid code ENZO+MHD
-presently the largest MHD cosmological runs in the market
- volumes ~ (50-200 Mpc)^3
- resolutions ~ 20-160 kpc

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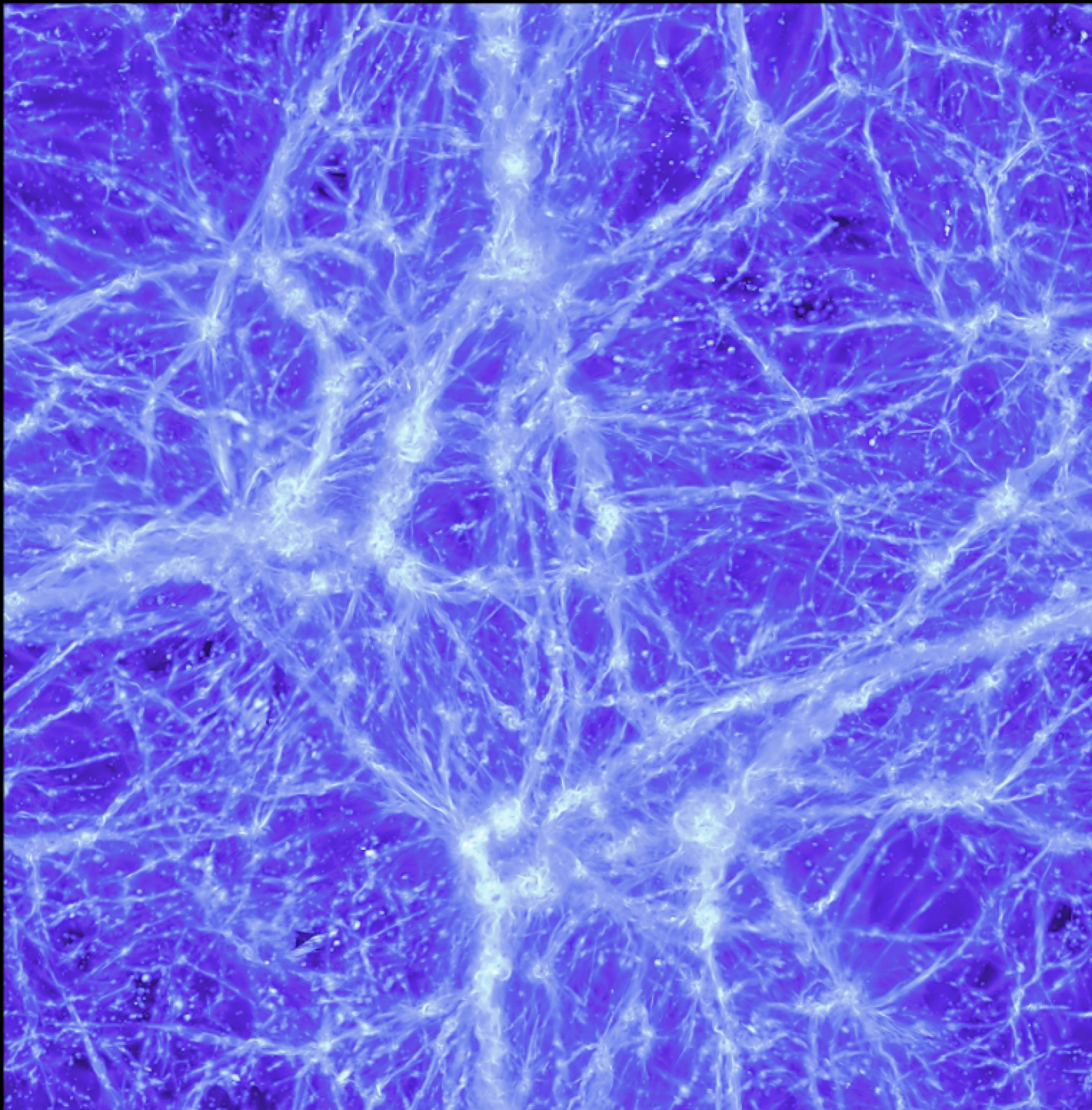

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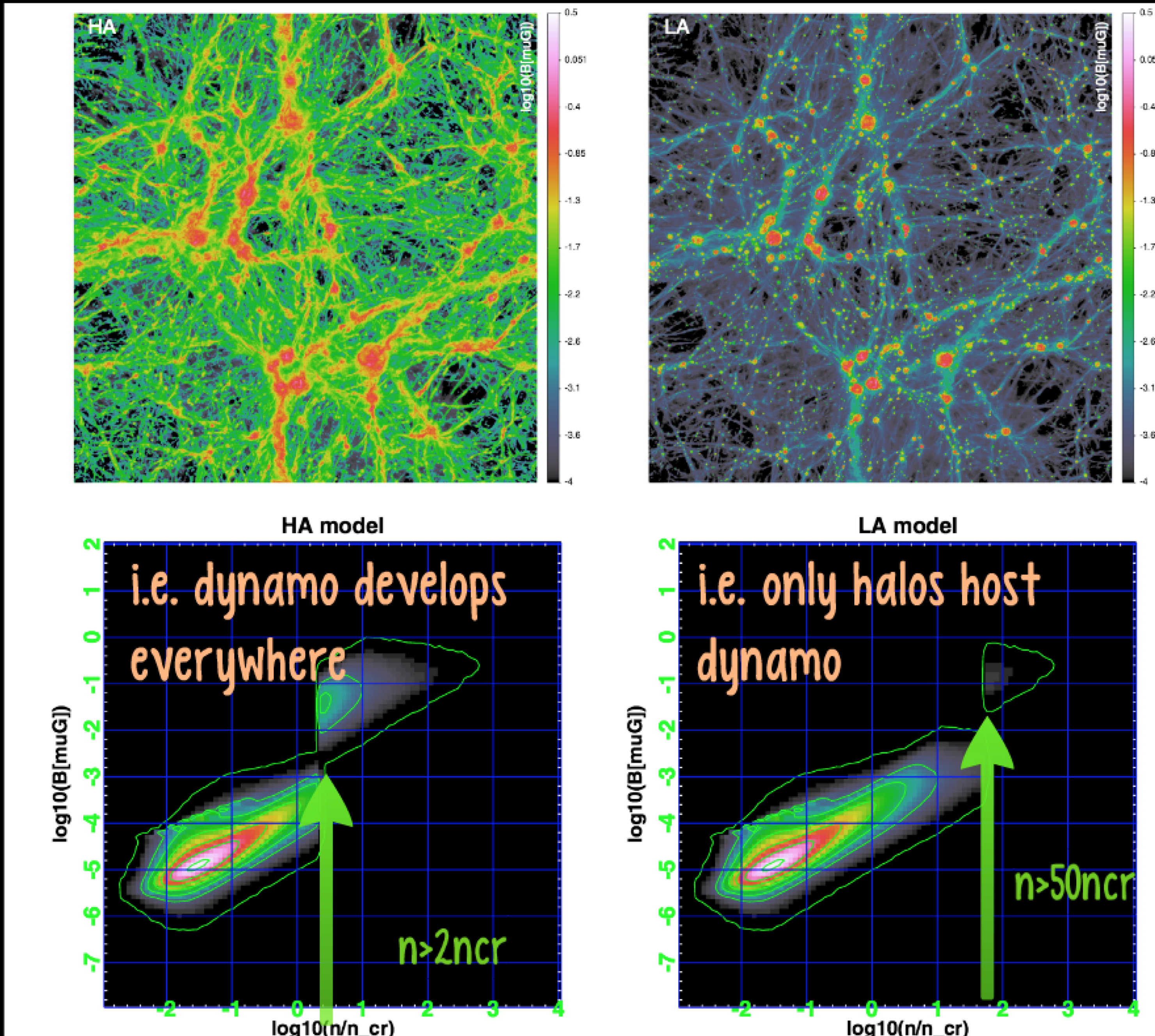
Magnetic field: MHD+renormalisation



~bracket uncertainties in the B-field

-ignores details of AGN, galaxy winds..

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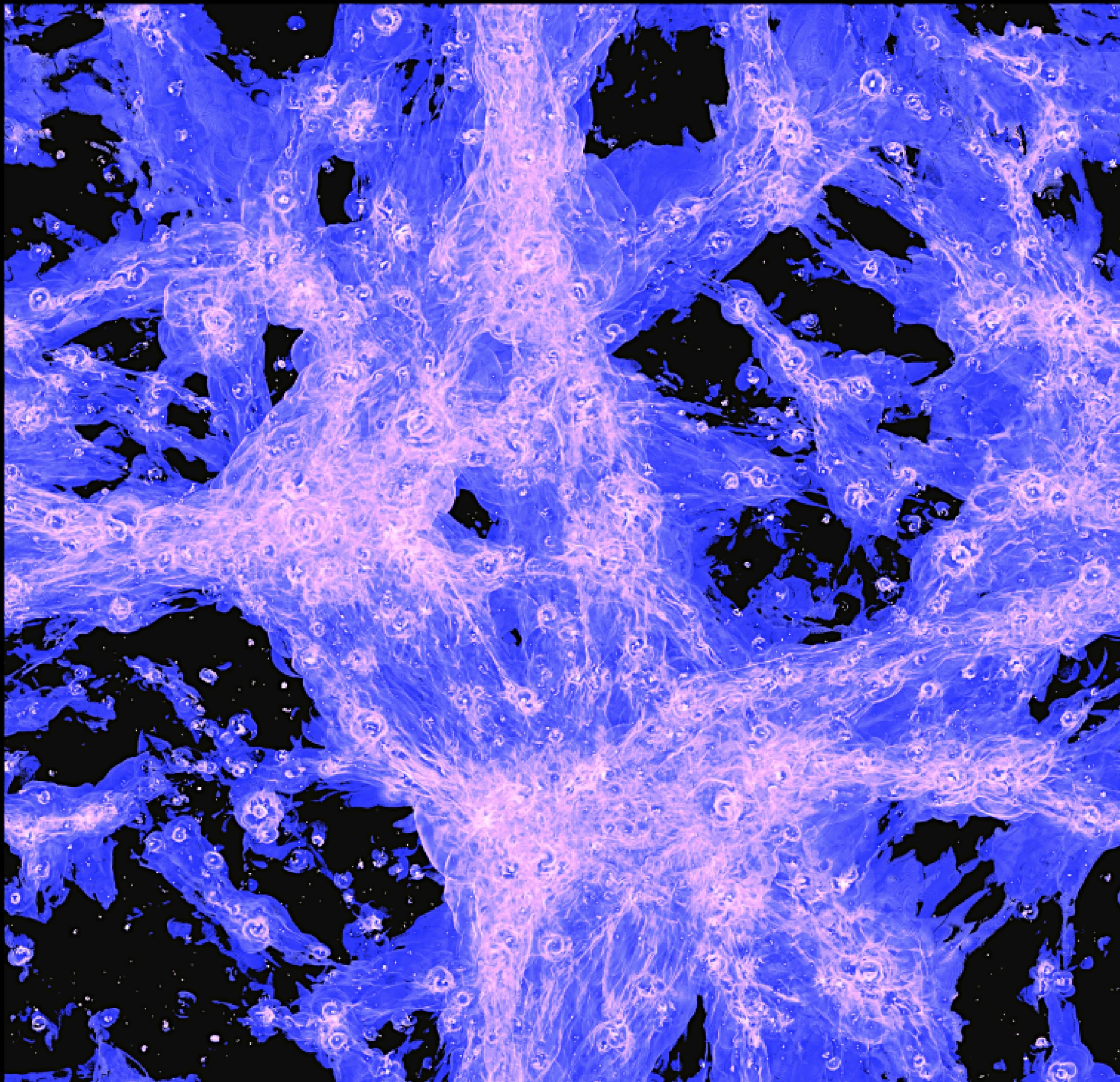

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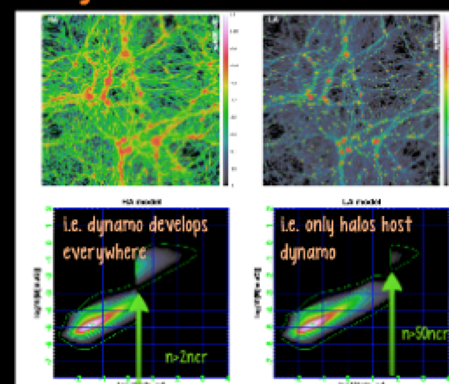

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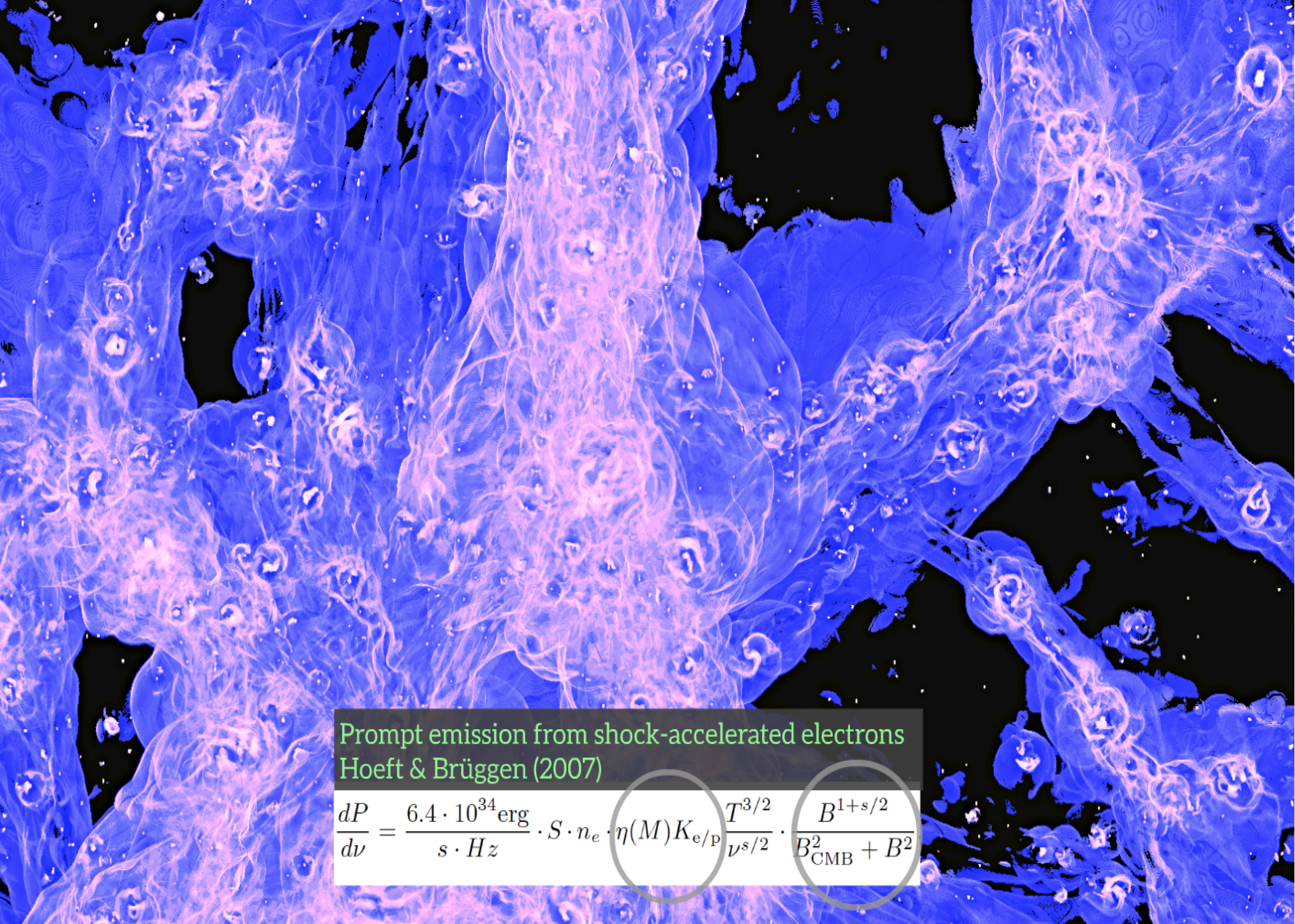


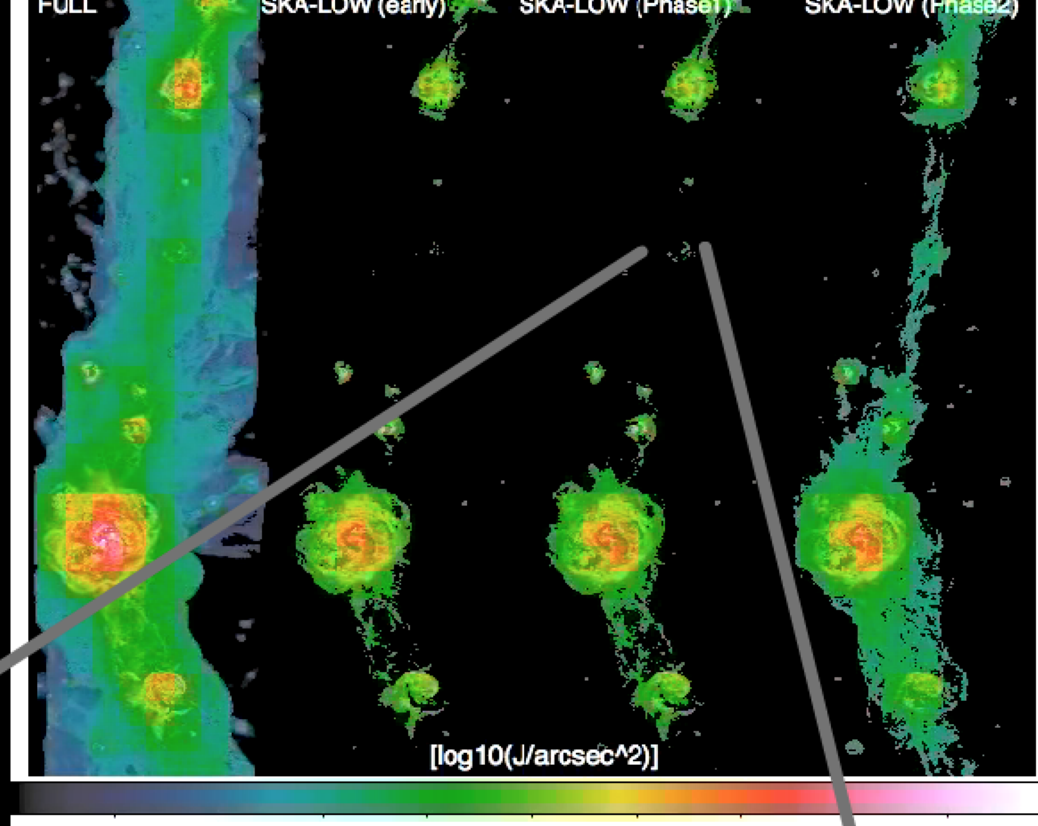
Prompt emission from shock-accelerated electrons
Hoeft & Brüggen (2007)

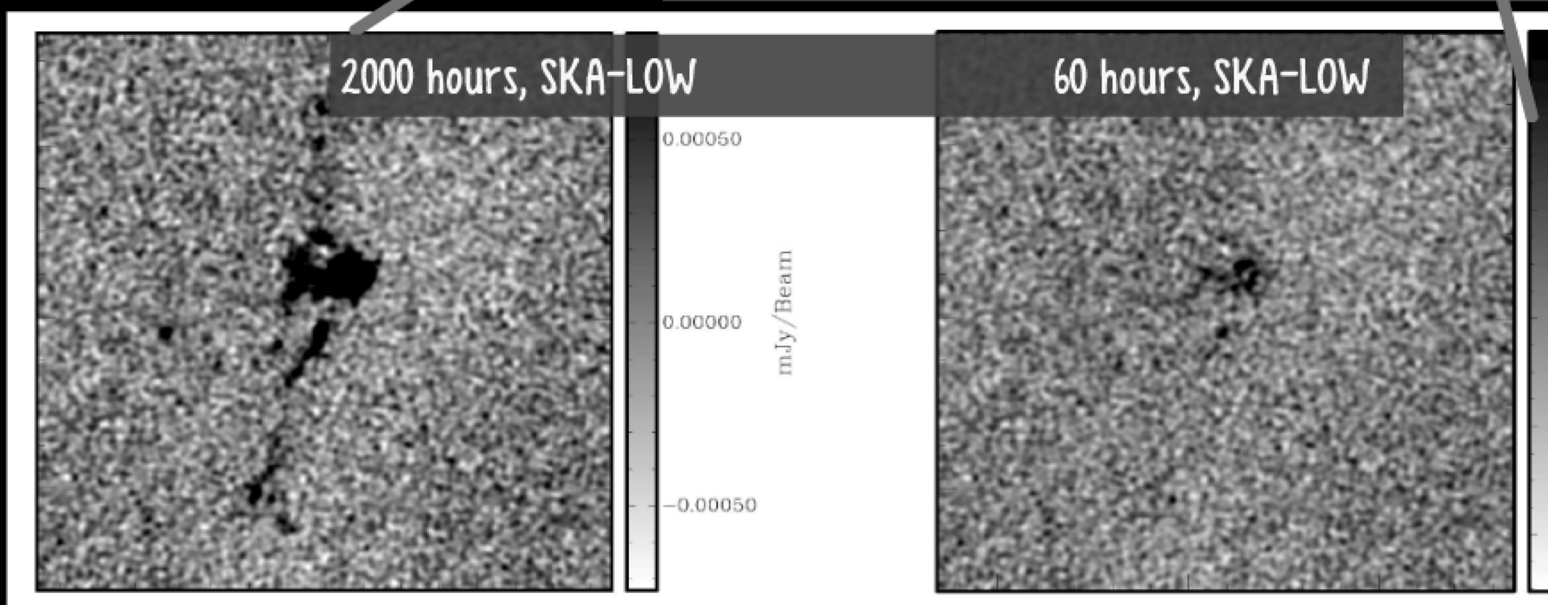
$$\frac{dP}{d\nu} = \frac{6.4 \cdot 10^{34}\mathrm{erg}}{s \cdot Hz} \cdot S \cdot n_e \cdot \eta(M) K_{\mathrm{e/p}} \frac{T^{3/2}}{\nu^{s/2}} \cdot \frac{B^{1+s/2}}{B_{\mathrm{CMB}}^2 + B^2}$$

SKA simulations

Mock radio observations

- FFT-baseline removal
- realistic exposure
- thermal/confusion noise
- pointed vs survey exposures





FV, Ferrari, Bonafede+2015 PoS

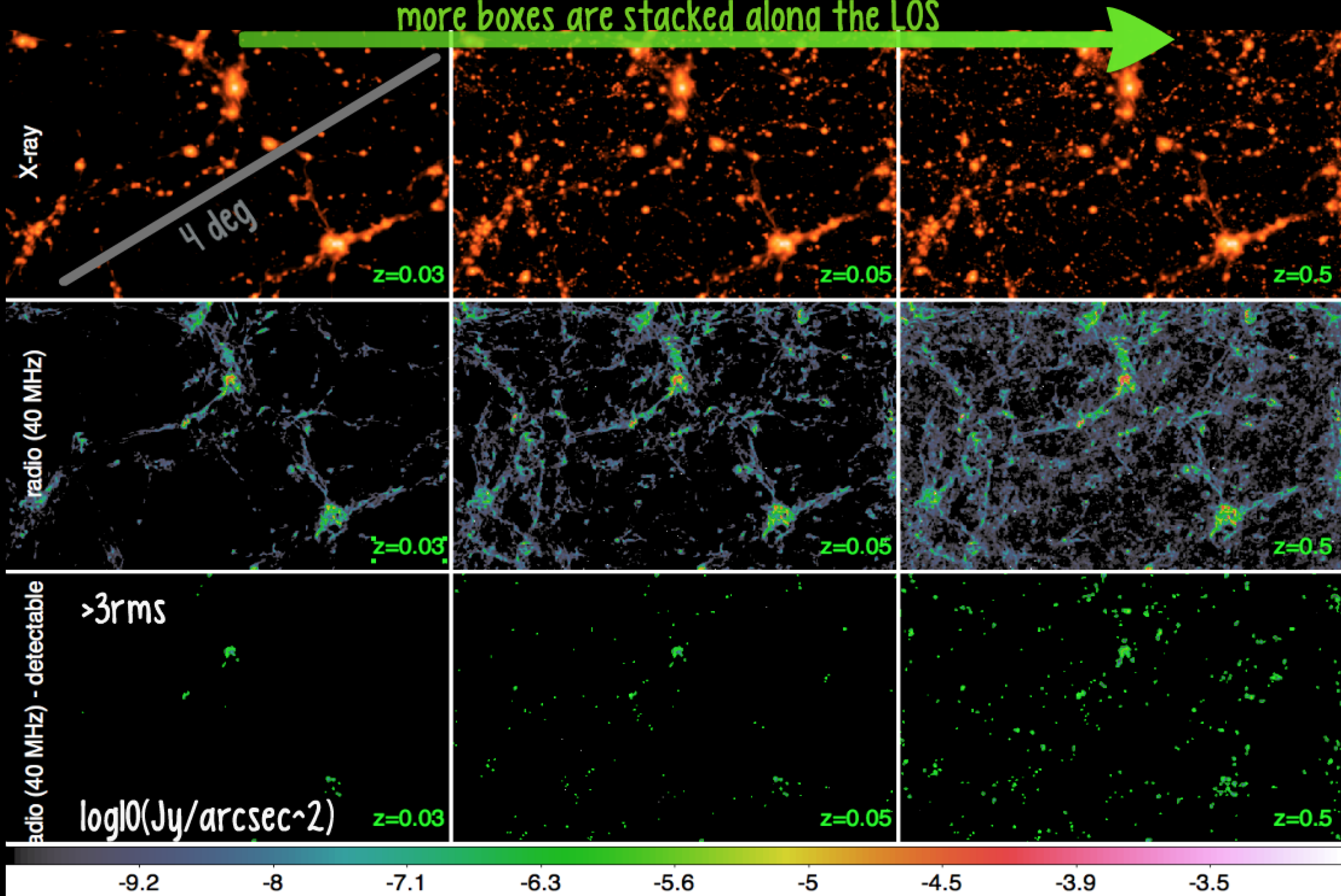
tests with SKA-simulator by R. Braun

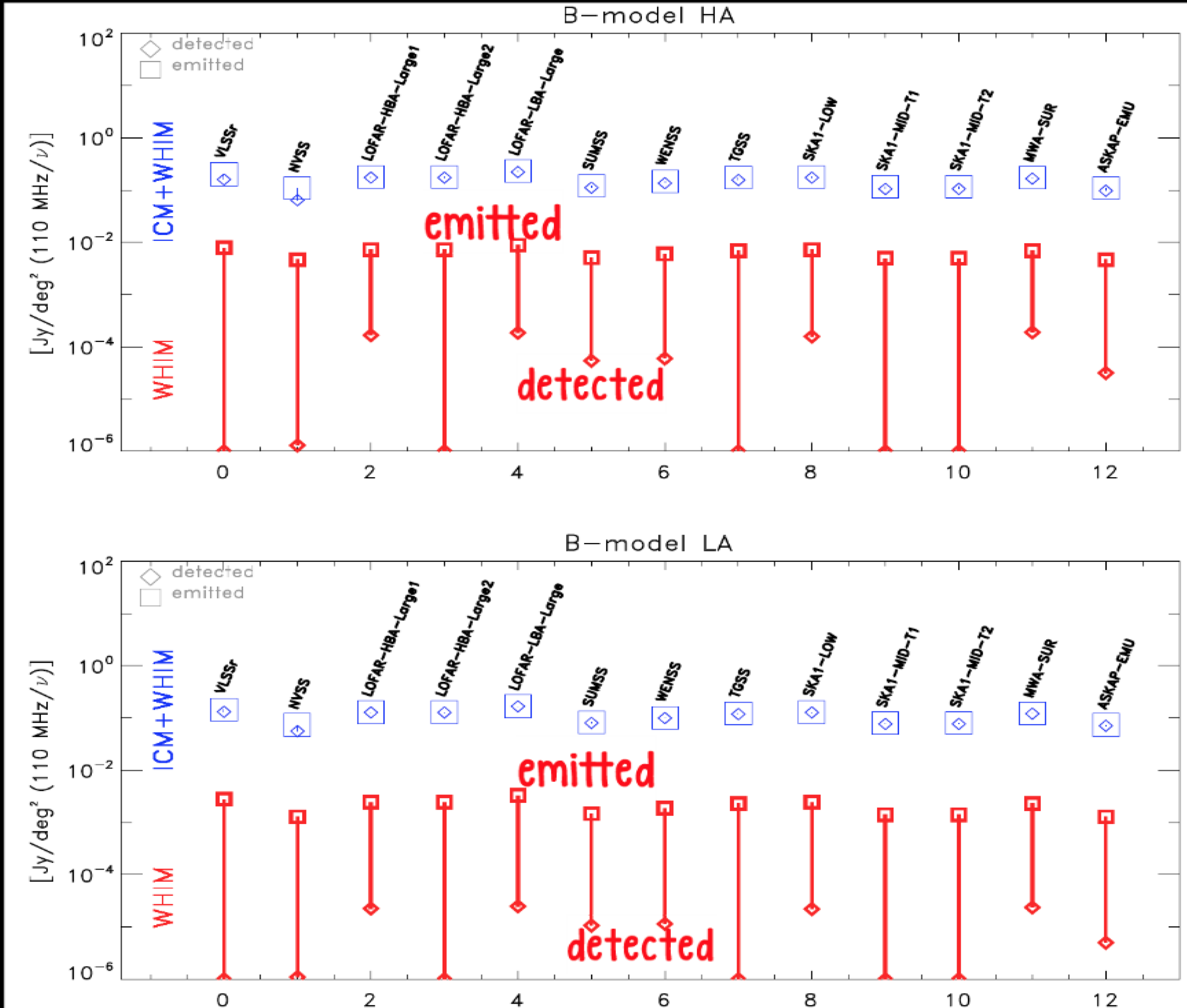
FV, Ferrari, Brüggen+2015 AA

parameters for 13 radio surveys

array	configuration/strategy	frequency [MHz]	resolution [arcsec]	min. baseline [m]	sensitivity [mJy/beam]	detection threshold [μJy/arcsec^2]
VLA	VLSSr	74	80	35	100.0	42.365
VLA	NVSS	1400	45	35	0.45	0.588
Westerboork	WENSS	330	54	36	3.6	3.268
GMRT	TGSS	150	20	100	5.0	33.098
Molonglo	SUMSS	840	43	15	1.0	1.307
LOFAR-HBA	Large Survey 1	120	25	40	0.25	1.059
LOFAR-LBA	Large Survey	40	25	40	2.0	8.473
LOFAR-HBA	Large Survey 2	120	5	40	0.1	10.591
MWA	Broadband Survey	150	120	7.7	10	1.838
SKA1-LOW	Cont. Survey	120	10	45	0.02	0.17
SKA1-MID	Band2 Wide Survey	1000	0.5	15	0.001	10.591
SKA1-MID	Band2 Deep Survey	1000	0.5	15	0.0002	2.118
ASKAP	EMU	1400	10	12	0.01	0.264

How much can be detected?





14 x 14 deg^2 area

ICM emission mostly detected
High-amplification:

WHIM emits ~ 5% ICM
~1% of WHIM emission is detectable

Low-amplification:

the detectable WHIM emission gets reduced by ~ 5-10

Radio emission & constraints

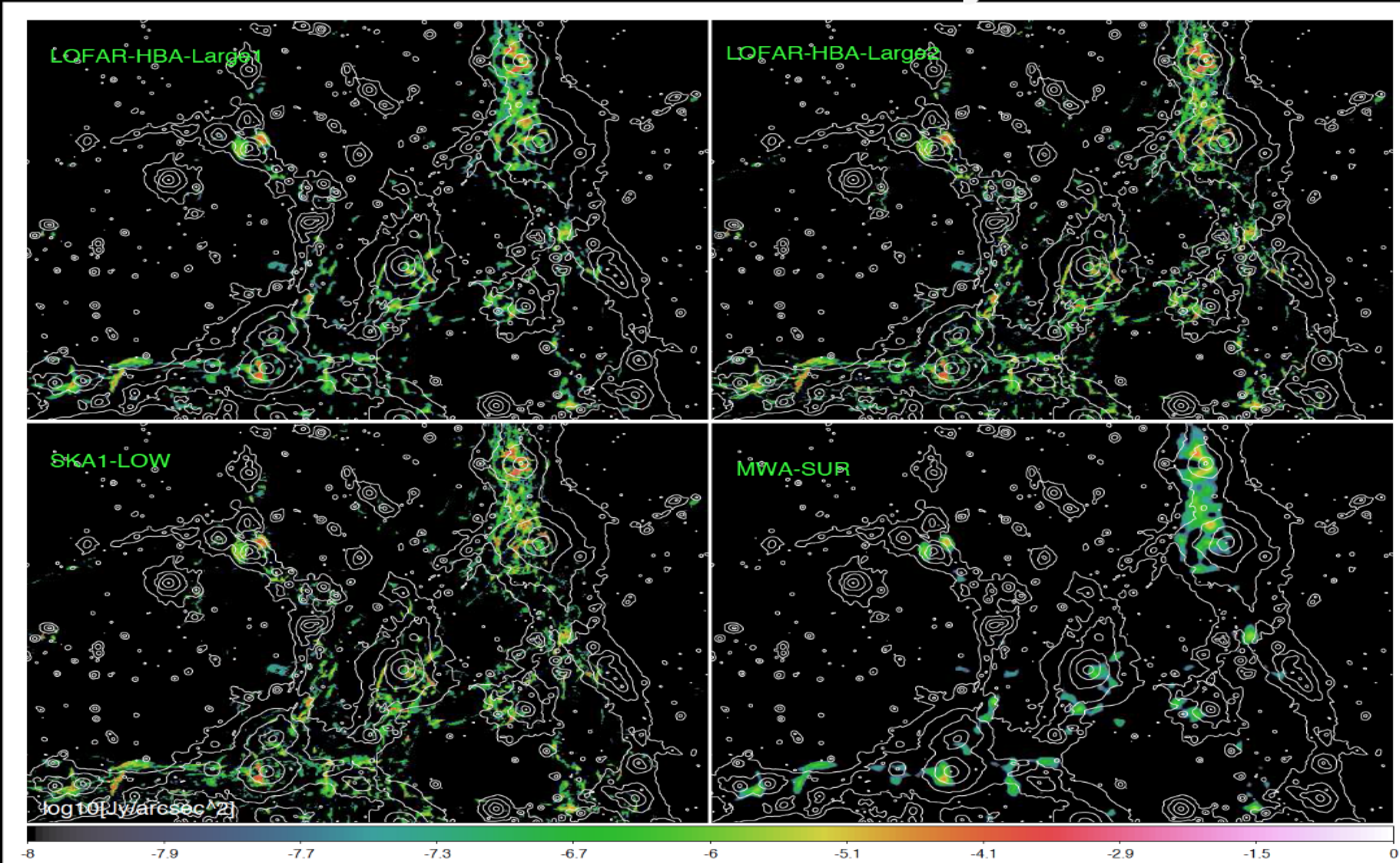
Average emission from the shocked WHIM

$$P_{\mathrm{WHIM}}(\nu) \sim 5 \times 10^{-3} \mathrm{Jy/deg^2} \frac{100\mathrm{MHz}}{\nu} \cdot \frac{\epsilon_{\mathrm{B}}}{0.01} \cdot \frac{\xi}{10^{-3}}$$

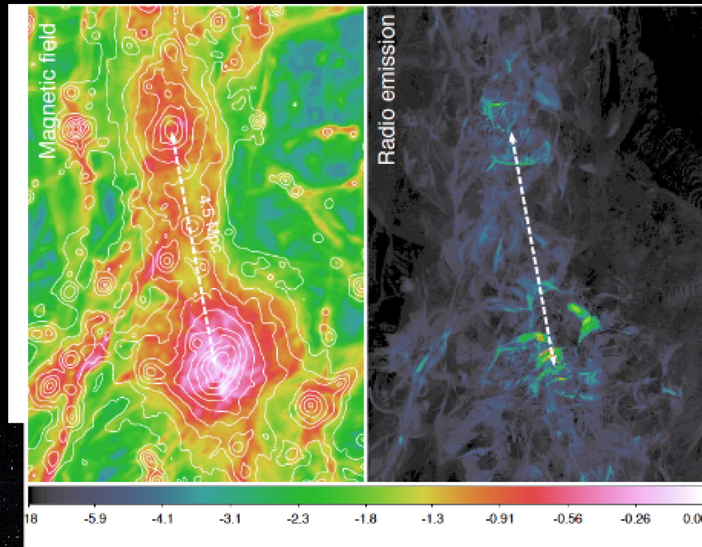
only ~1-2% of this is detectable

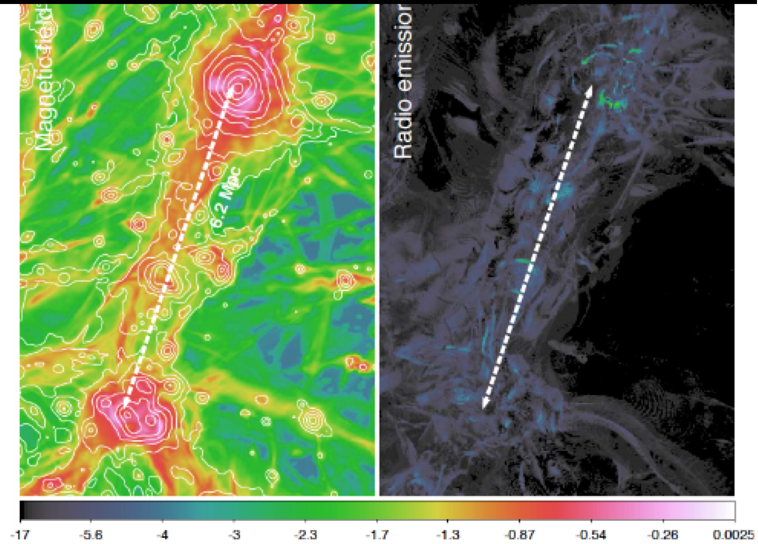
-> complementary techniques : stacking

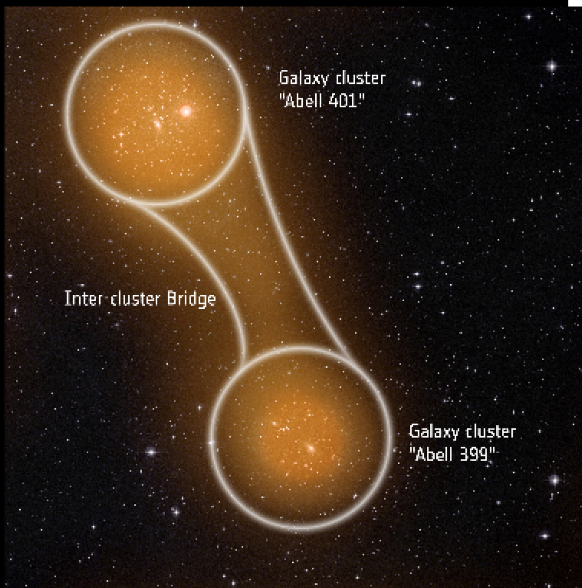
Resolution matters: <10" needed to distinguish ICM from WHIM

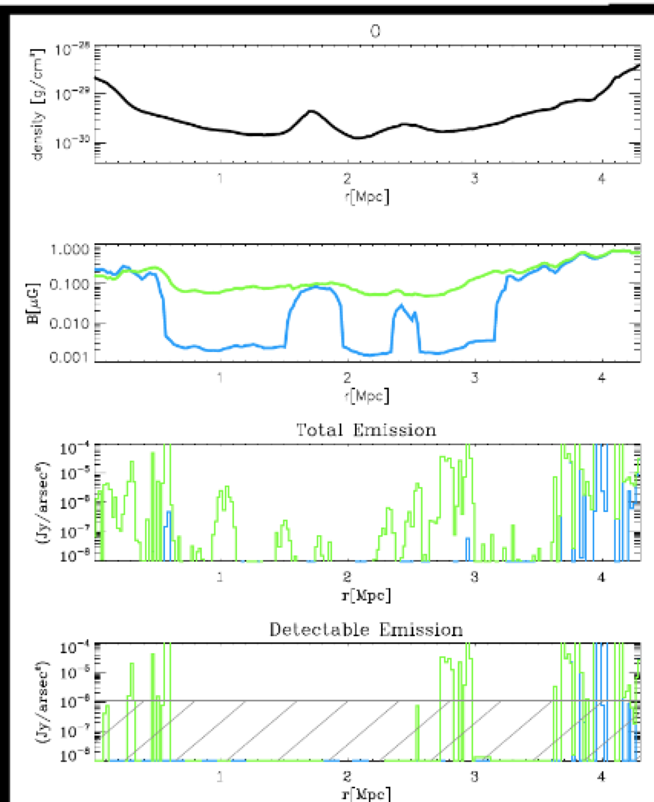


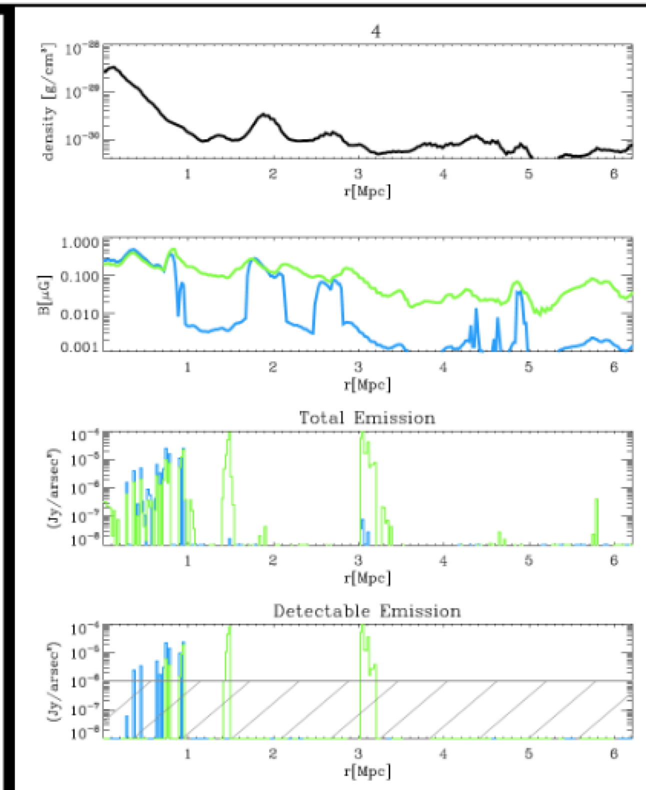
Filaments connecting clusters







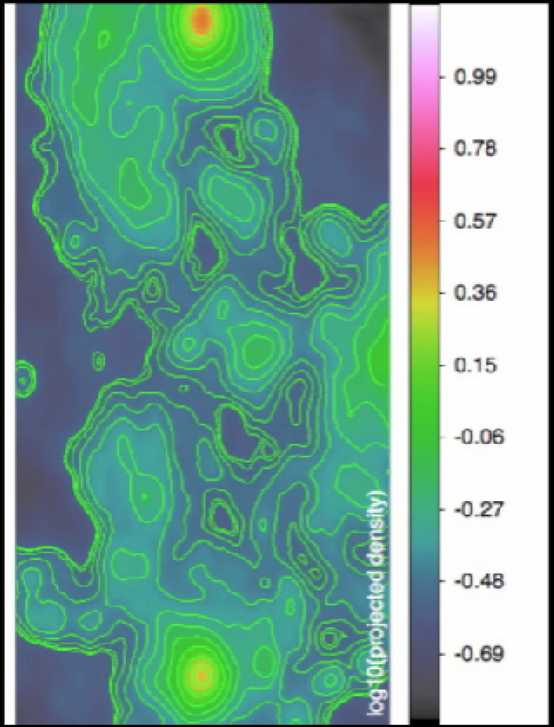




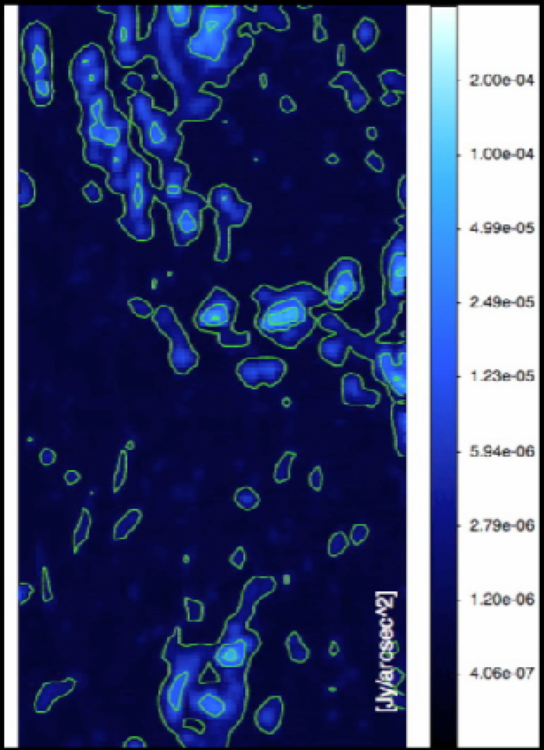
- can detect B ~ 0.1 uG fields
-mostly from shocks in substructures

Stacking of filaments in the EMU survey (Testing!)

projected density



radio emission



- 70 pairs of clusters with M1,M2 > 5e13 Msol , 8 < distance < 12 Mpc

SUMMARY

- The radio cosmic web can become probe of magnetogenesis, particle acceleration and WHIM physics

  - Best options for surveys:

sensitivy < 0.1 muJ/arcsec^2 , freq<300MHz, wide-field > 1 deg, resolution<10".

... still, only ~1% of the emission is within reach

Complementary tools:

-Faraday Rotation / Synthesis: probably best for close pairs of clusters

-Polarisation: good to reduce dyn.range

-Stacking: under testing, non-trivial

-HI : best to probe circumgalactic IGM

THANKS