

Magnetic fields and non-thermal emission in galaxy clusters: SKA perspective

L. Feretti, IRA-INAF, Bologna, MA4 meeting,
6/6/2016

Main open questions :

- strength and structure (profile, power spectrum, ..)
- formation, amplification, evolution
- connection to other physical parameters (density, temperature, ...)
- connection to large scale structure
- link to relativistic particles (propagation, reacceleration, ..)

Clusters of galaxies:

being the largest systems in the Universe, they represent an ideal laboratory to test theories for the origin of extragalactic magnetic fields

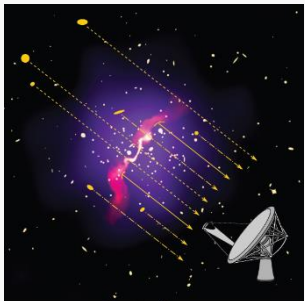
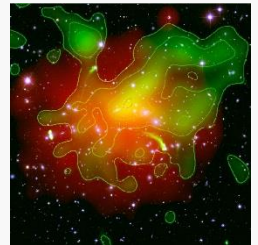
Most of what we know about extragalactic magnetic fields derives from **radio observations** :

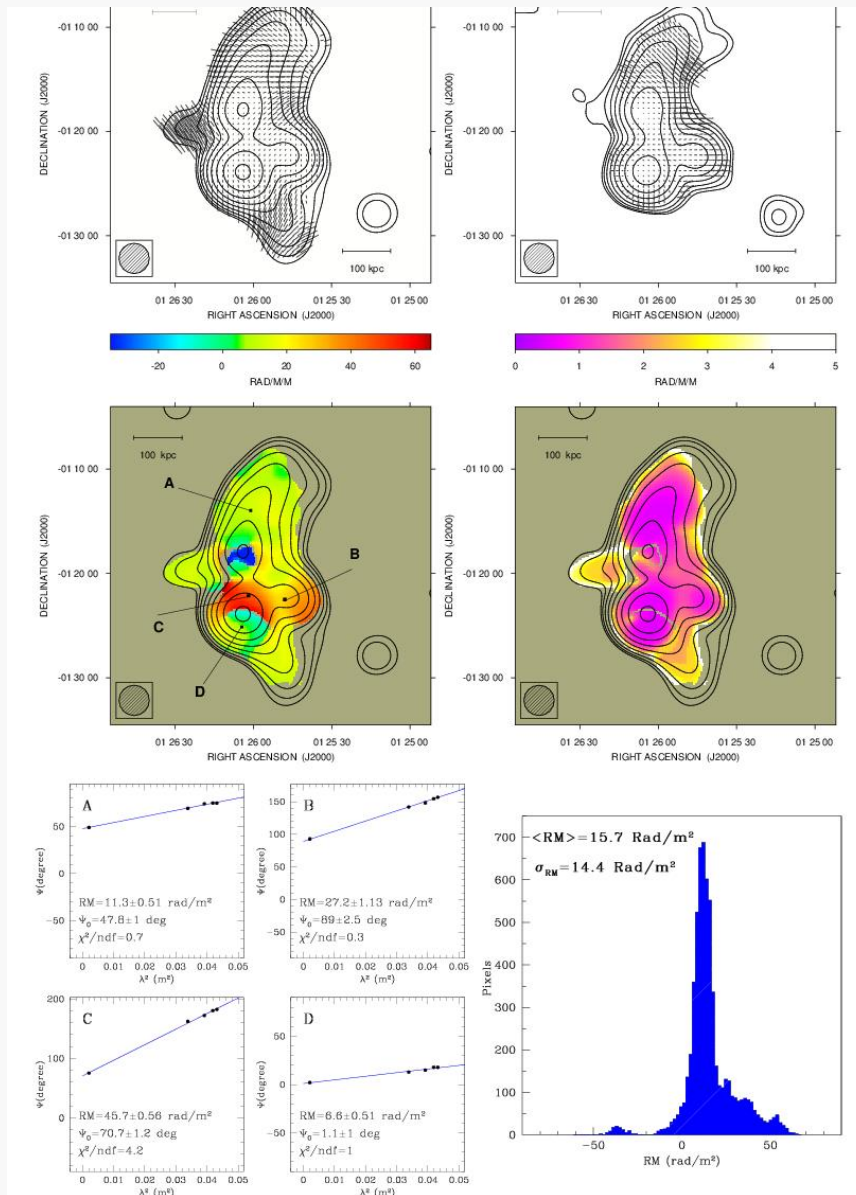
1 - Synchrotron emission (direct measurement)

a- total intensity \rightarrow field strength \perp -equipartition

b- polarization \rightarrow field orientation and degree of ordering

2 - Faraday rotation (indirect measurement)
 \rightarrow field strength \parallel and structure





Example of RM

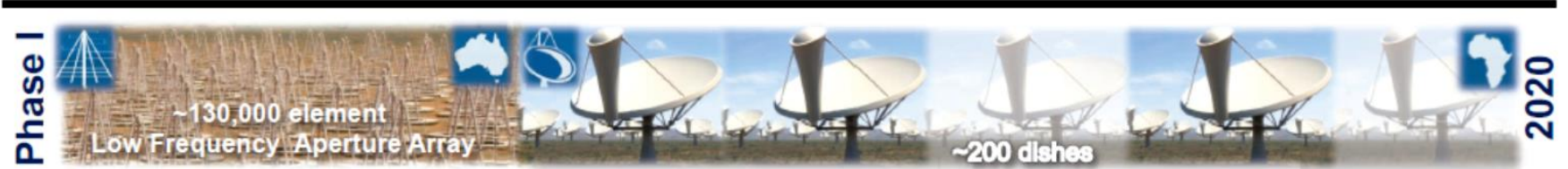
A194 :

VLA around 1.4 GHz - 4 IF
SRT at 6.6 GHz

(SMOG, Murgia et al.)

SKA : Largest and most sensitive radio telescope (cm)
Up to 1 million m² collecting area distributed over
a distance of ~3000 km on large frequency range
(70 MHz - 10+ GHz)

SKA 1



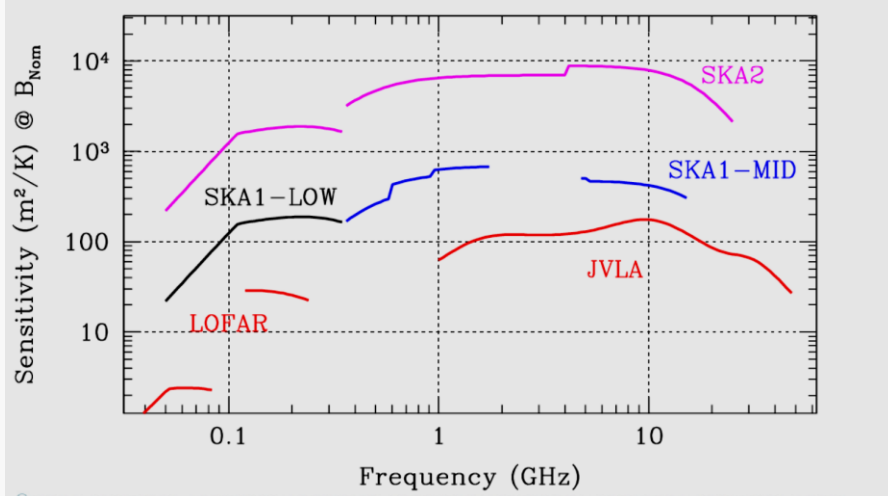
SKA-LOW: 50 – 350 MHz

SKA-MID Band1: 0.35 – 1.05 GHz
Band2: 0.95 – 1.76 GHz
Band3: 1.65 – 3.05 GHz
Band4: 2.8 – 5.18 GHz
Band5: 4.6 – 13.8 GHz

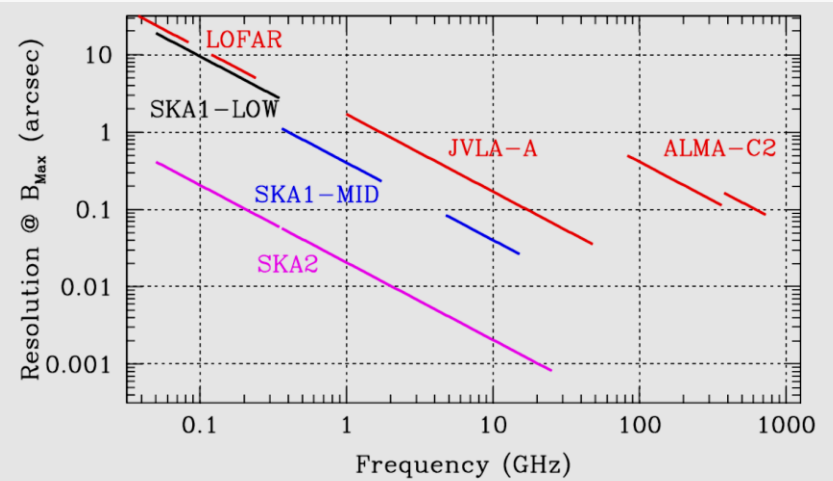
SKA 2



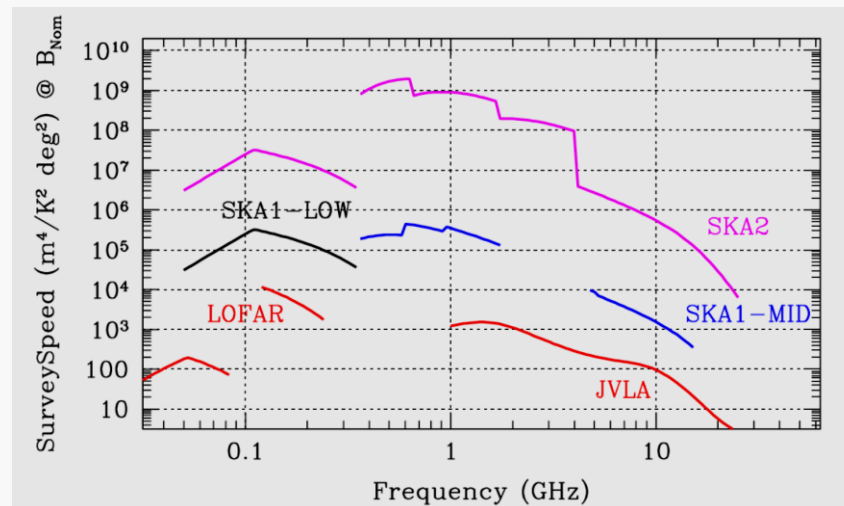
Sensitivity



Resolution

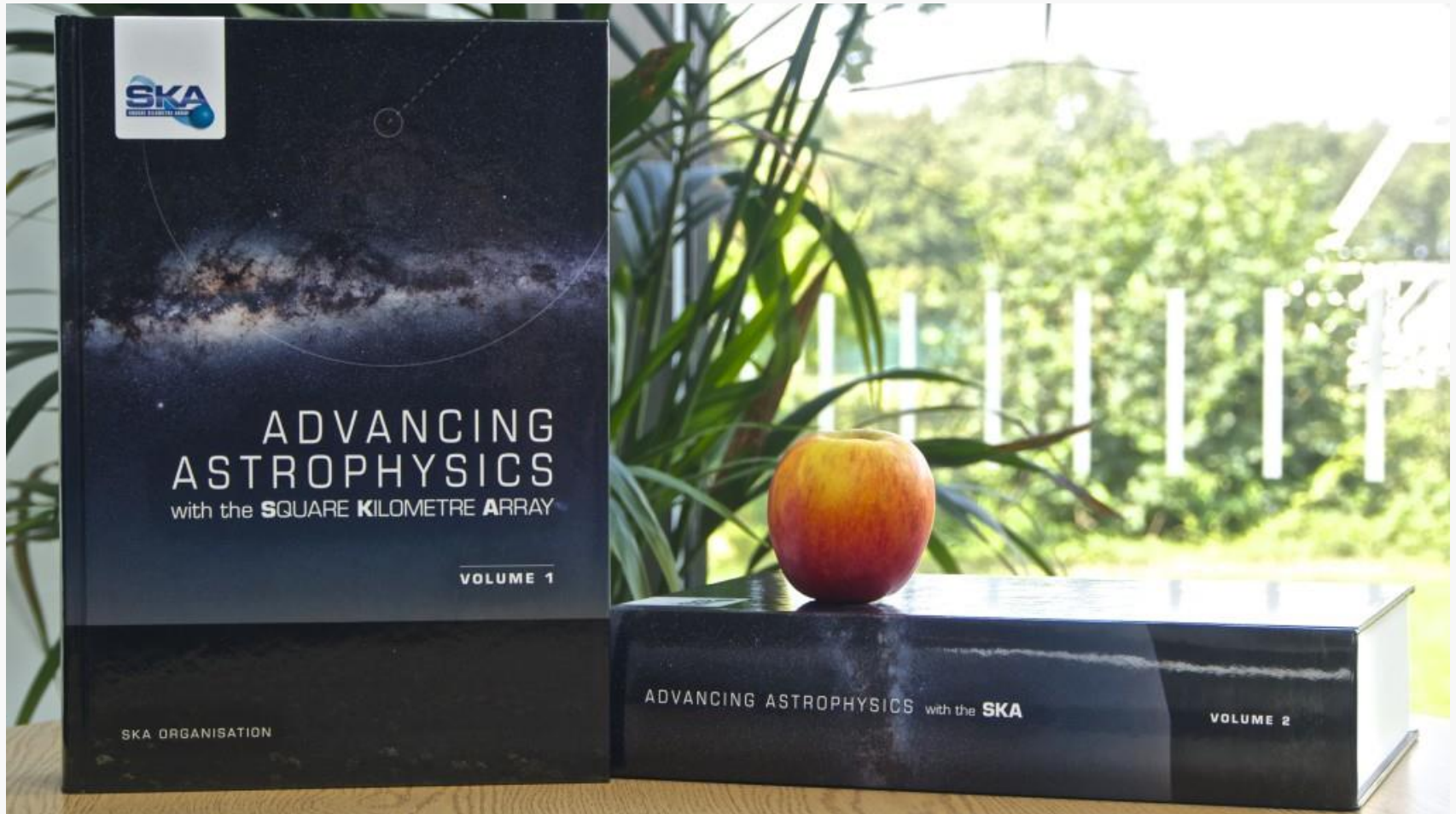


Survey speed



Science book 2015

2000 pages, 135 chapters, 1200 authors, 8.8 kg



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Session 5: The Continuum Universe

Revealing the Physics and Evolution of Galaxies and Galaxy Clusters with SKA Continuum Surveys

PoS(AASKA14)067 [pdf](#) I. Prandoni and N. Seymour

The star-formation history of the Universe with the SKA

PoS(AASKA14)068 [pdf](#) M. Jarvis, N. Seymour, J. Afonso, P. Best, R.J. Beswick, M. Huynh, E. Murphy, I. Prandoni, E. Schinnerer, C. Simpson, M. Vaccari, S. White and I. Heywood

Exploring AGN Activity over Cosmic Time with the SKA

PoS(AASKA14)069 [pdf](#) V. Smolcic, P. Padovani, J. Delhaize, I. Prandoni, N. Seymour, M. Jarvis, J. Afonso, M. Magliocchetti, M. Huynh, M. Vaccari and A. Karim

SKA studies of nearby galaxies: star-formation, accretion processes and molecular gas across all environments

PoS(AASKA14)070 [pdf](#) R.J. Beswick, E. Brinks, M. Pérez-Torres, A.M.S. Richards, S. Aalto, A. Alberdi, M.K. Argo, I. van Bemmel, J.E. Conway, C. Dickinson, D.M. Fenech, M.D. Gray, H.R. Kloeckner, E. Murphy, T.W.B. Mudrow, M.W. Peel, A. Rushton and E. Schinnerer

Identifying the first generation of radio powerful AGN in the Universe with the SKA

PoS(AASKA14)071 [pdf](#) J. Afonso, J. Casanellas, I. Prandoni, M. Jarvis, S. Lorenzoni, M. Magliocchetti and N. Seymour

Cluster Radio Halos at the crossroads between astrophysics and cosmology in the SKA era

PoS(AASKA14)073 [pdf](#) R. Cassano, G. Bernardi, G. Brunetti, M. Brüggen, T. Clarke, D. Dallacasa, K. Dolag, S. Ettori, S. Giacintucci, C. Giocoli, M. Gitti, M. Johnston-Hollitt, R. Kale, M. Markevich, R. Norris, M.P. Pommier, G. Pratt, H.J.A. Rottgering and T. Venturi

Non-thermal emission from galaxy clusters: feasibility study with SKA

PoS(AASKA14)075 [pdf](#) C. Ferrari, A. Dabbech, O. Smirnov, S. Makhathini, J.S. Kenyon, M. Murgia, F. Govoni, D. Mary, E. Slezak, F. Vazza, A. Bonafede, M. Brugger, M. Johnston-Hollitt, S. Dehghan, L. Ferretti, G. Giovannini, V. Vacca, M.W. Wise, M. Gitti, M. Arnaud, G. Pratt, K. Zarb Adami and S. Colafrancesco

The SKA view of cool-core clusters: evolution of radio mini-halos and AGN feedback

PoS(AASKA14)076 [pdf](#) M. Gitti, P. Tozzi, G. Brunetti, R. Cassano, D. Dallacasa, A. Edge, L. Feretti, C. Ferrari, S. Giacintucci, G. Giovannini, M. Hogan and T. Venturi

Morphological classification of radio sources for galaxy evolution and cosmology with the SKA

PoS(AASKA14)081 [pdf](#) S. Makhathini, M. Jarvis, O. Smirnov and I. Heywood

Radio Observations of Star Forming Galaxies in the SKA era

PoS(AASKA14)082 [pdf](#) C. Mancuso, A. Lapi, Z.Y. Cai, M. Negrello, G. De Zotti, F. Perrotta and L. Danese

The SKA view of the Interplay between SF and AGN Activity and its role in Galaxy Evolution

PoS(AASKA14)083 [pdf](#) K. McAlpine, I. Prandoni, M. Jarvis, N. Seymour, P. Padovani, P. Best, C. Simpson, D. Guidetti, E. Murphy, M. Huynh, M. Vaccari, S. White, R.J. Beswick, J. Afonso, M. Magliocchetti and M. Bondi

Strong Gravitational Lensing with the SKA

PoS(AASKA14)084 [pdf](#) J. McKean, N. Jackson, S. Vegetti, M. Rybak, S. Serjeant, L.V.E. Koopmans, R.B. Metcalf, C. Fassnacht, P.J. Marshall and M. Pandey-Pommier

The Astrophysics of Star Formation Across Cosmic Time at >10 GHz with the Square Kilometre Array

PoS(AASKA14)085 [pdf](#) E. Murphy, M. Sargent, R.J. Beswick, C. Dickinson, L. Hunt, M. Huynh, M. Jarvis, A. Karim, M. Krause, I. Prandoni, N. Seymour, E. Schinnerer, F. Tabatabaei, J. Wagg and I. Heywood

The SKA Mid-frequency All-sky Continuum Survey: Discovering the unexpected and transforming radio-astronomy

PoS(AASKA14)086 [pdf](#) R. Norris, K. Basu, M. Brown, E. Carretti, A.D. Kapinska, I. Prandoni, L. Rudnick and N. Seymour

The physics of the radio emission in the quiet side of the AGN population with the SKA

PoS(AASKA14)087 [pdf](#) M. Orienti, F. D'Ammando, M. Giroletti, G. Giovannini and F. Panessa

Radio investigation of Ultra-Luminous X-ray (ULX) Sources in the SKA Era

PoS(AASKA14)091 [pdf](#) A. Wolter, A. Rushton, M. Mezcu, D. Cseh, F. Pintore, I. Prandoni, Z. Paragi and L. Zampieri

The SKA and Galaxy Cluster Science with the Sunyaev-Zel'dovich Effect

PoS(AASKA14)170 [pdf](#) K. Grainge, S. Borgani, S. Colafrancesco, C. Ferrari, A. Scaife, P. Marchegiani, S. Emritte and J. Weller

Astronomy Below the Survey Threshold in the SKA Era

PoS(AASKA14)172 [pdf](#) J. Zwart, J. Wall, A. Karim, C. Jackson, R. Norris, J. Condon, J. Afonso, M. Jarvis, F. Navarrete, I. Prandoni, E. Rigby, H.J.A. Rottgering, M. Santos, M. Sargent, N. Seymour, R. Taylor, T. Vernstrom and I. Heywood

Session 6: Magnetism

Using SKA Rotation Measures to Reveal the Mysteries of the Magnetised Universe

PoS(AASKA14)092 [pdf](#) M. Johnston-Hollitt, F. Govoni, R. Beck, S. Dehghan, L. Pratley, T. Akahori, G. Heald, I. Agudo, A. Bonafede, E. Carretti, T. Clarke, S. Colafrancesco, T.A. Ensslin, L. Feretti, B. Gaensler, M. Haverkorn, S.A. Mao, N. Oppermann, L. Rudnick, A. Scaife, D. Schnitzeler, J. Stil, A.R. Taylor and V. Vacca

Studies of Relativistic Jets in Active Galactic Nuclei with SKA

PoS(AASKA14)093 [pdf](#) I. Agudo, M. Boettcher, H.D.E. Falcke, M. Georgantopoulos, G. Ghisellini, G. Giovannini, M. Giroletti, L. Gurvits, J.L. Gómez, R. Laing, M.L. Lister, J.M. Martí, E. Meyer, Y. Mizuno, S. O'Sullivan, P. Padovani, Z. Paragi, M. Peruch, D. Schleicher, L. Stawarz, N. Vlahakis and J. Wardle

Structure, dynamical impact and origin of magnetic fields in nearby galaxies in the SKA era

PoS(AASKA14)094 [pdf](#) R. Beck, D. Bomans, S. Colafrancesco, R.J. Dettmar, K. Ferrière, A. Fletcher, G. Heald, V. Heesen, C. Horellou, M. Krause, Y.Q. Lou, S.A. Mao, R. Paladino, E. Schinnerer, D. Sokoloff, J. Stil and F. Tabatabaei

Unravelling the origin of large-scale magnetic fields in galaxy clusters and beyond through Faraday Rotation Measures with the SKA

PoS(AASKA14)095 [pdf](#) A. Bonafede, F. Vazza, M. Brüggen, T. Akahori, E. Carretti, S. Colafrancesco, L. Feretti, C. Ferrari, G. Giovannini, F. Govoni, M. Johnston-Hollitt, M. Murgia, A. Scaife, V. Vacca, F. Govoni, L. Rudnick and A. Scaife

Measuring magnetism in the Milky Way with the Square Kilometre Array

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Filaments of the radio cosmic web: opportunities and challenges for SKA

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Probing the nature of Dark Matter with the SKA

PoS(AASKA14)100 [pdf](#) S. Colafrancesco, M. Regis, P. Marchegiani, G. Beck, R. Beck, H. Zechlin, A. Lobanov and D. Horns

Using Tailed Radio Galaxies to Probe the Environment and Magnetic Field of Galaxy Clusters in the SKA Era

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SKA studies of in situ synchrotron radiation from molecular clouds

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Broadband Polarimetry with the Square Kilometre Array: A Unique Astrophysical Probe

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Mega-parsec scale magnetic fields in low density regions in the SKA era: filaments connecting galaxy clusters and groups

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Cluster magnetic fields through the study of polarized radio halos in the SKA era

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Magnetic Field Tomography in Nearby Galaxies with the Square Kilometre Array

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Kinematics and Dynamics of kiloparsec-scale Jets in Radio Galaxies with SKA

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Giant radio galaxies as probes of the ambient WHIM in the era of the SKA

PoS(AASKA14)109 [pdf](#) B. Peng, R.R. Chen and R. Strom

Measuring Magnetic Fields Near and Far with the SKA via the Zeeman Effect

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Stacking for Cosmic Magnetism with SKA Surveys

PoS(AASKA14)112 [pdf](#) J. Stil and B. Keller

SKA Deep Polarization and Cosmic Magnetism

PoS(AASKA14)113 [pdf](#) R. Taylor, I. Agudo, T. Akahori, R. Beck, B. Gaensler, G. Heald, M. Johnston-Hollitt, M. Langer, L. Rudnick, A. Scaife, D. Schleicher, J. Stil and D. Ryu

Statistical methods for the analysis of rotation measure grids in large scale structures in the SKA era

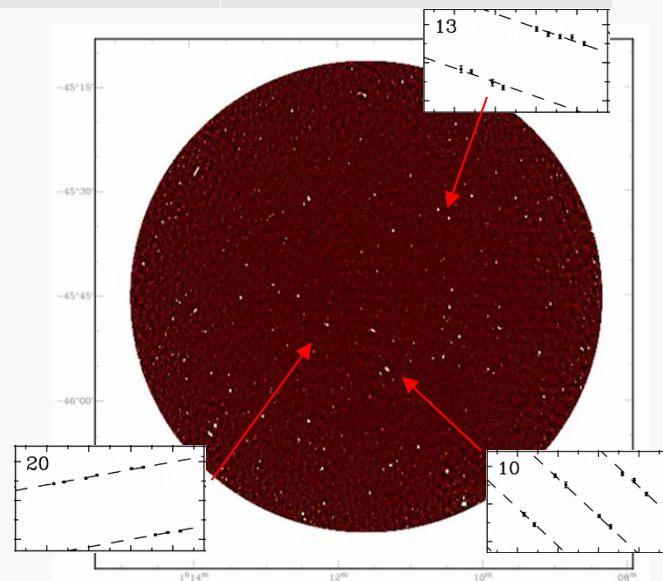
PoS(AASKA14)114 [pdf](#) V. Vacca, N. Oppermann, T.A. Ensslin, M. Selig, H. Junklewitz, M. Greiner, J. Jasche, C.A. Hales, M. Reneicke, E. Carretti, L. Feretti, C. Ferrari, G. Giovannini, F. Govoni, C. Horellou, S. Ideuchi, M. Johnston-Hollitt, M. Murgia, R. Paladino, R. Pizzo and A. Scaife

SKA1 Polarization Surveys

Instrument	Frequency	Field of View	Resolution	Sensitivity
SKA1-MID Band 2	1-1.7 GHz	All sky	$\sim 2''$	$\sim 4 \mu\text{Jy/beam}$
SKA1-MID Band 2-3	1- 3 GHz	4000 deg^2	$\sim 1''$	$\sim 75 \text{ nJy/beam}$
SKA1-MID Band1	0.35–1 GHz	20 deg^2	$\sim 3''$	$\sim 0.2 \mu\text{Jy/beam}$

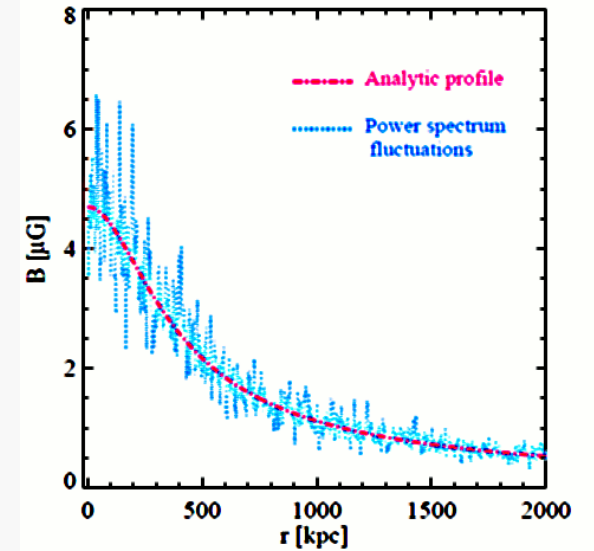
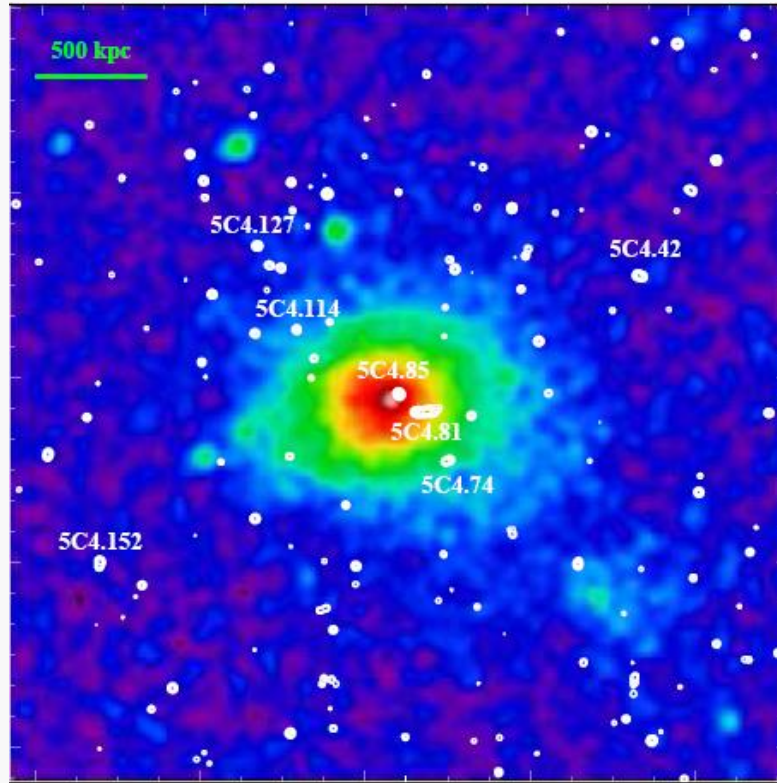
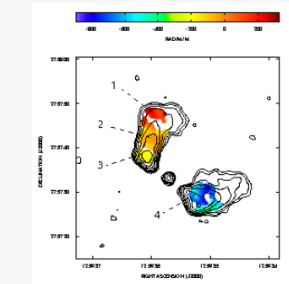
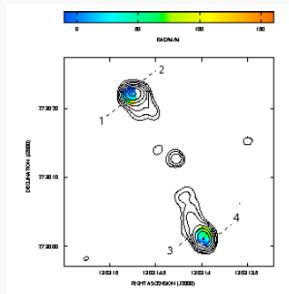
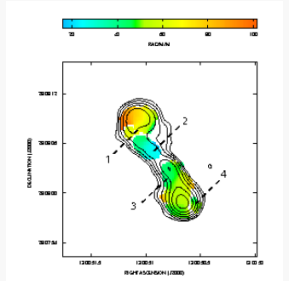
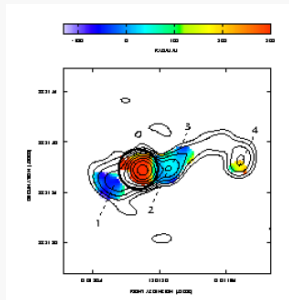
RM Grid: 10^7 sources $\rightarrow \sim 300 / \text{deg}^2$
high precision magnetism from pc to Mpc

Polarization of faint objects
Polarization of radio halos
Polarization in filaments and cosmic web



Coma Cluster

Bonafede et al. 2010



Magnetic field

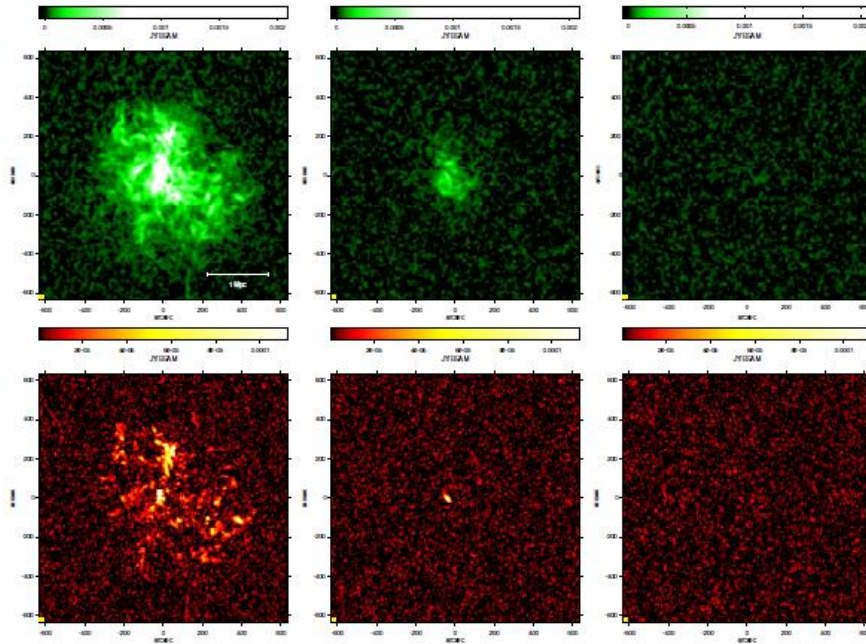
- Strength
- Structure
- Radial decline

Currently with 7
sources
SKA ~1000 sources
→ Many clusters
→ Distant clusters

Polarization in Radio Halos :

expected with turbulent magnetic field

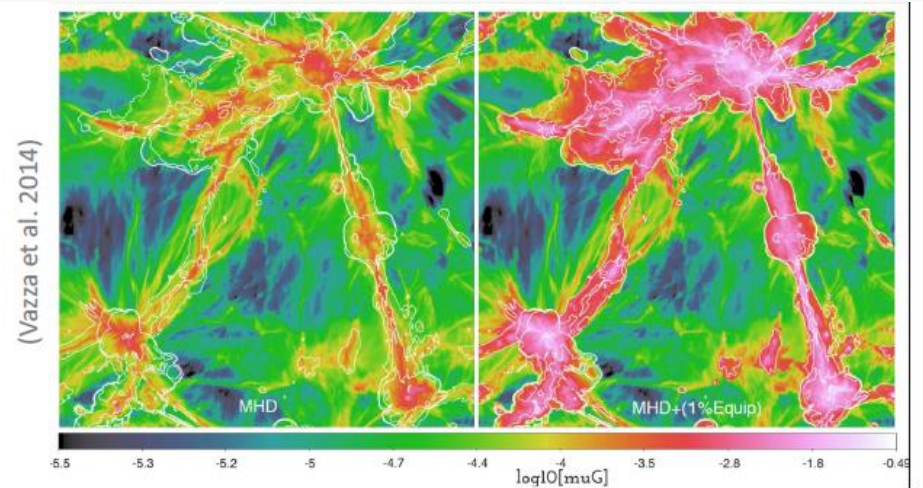
→ need SKA to detect



Govoni et al 2013

Vacca et al 2010

Cosmic web

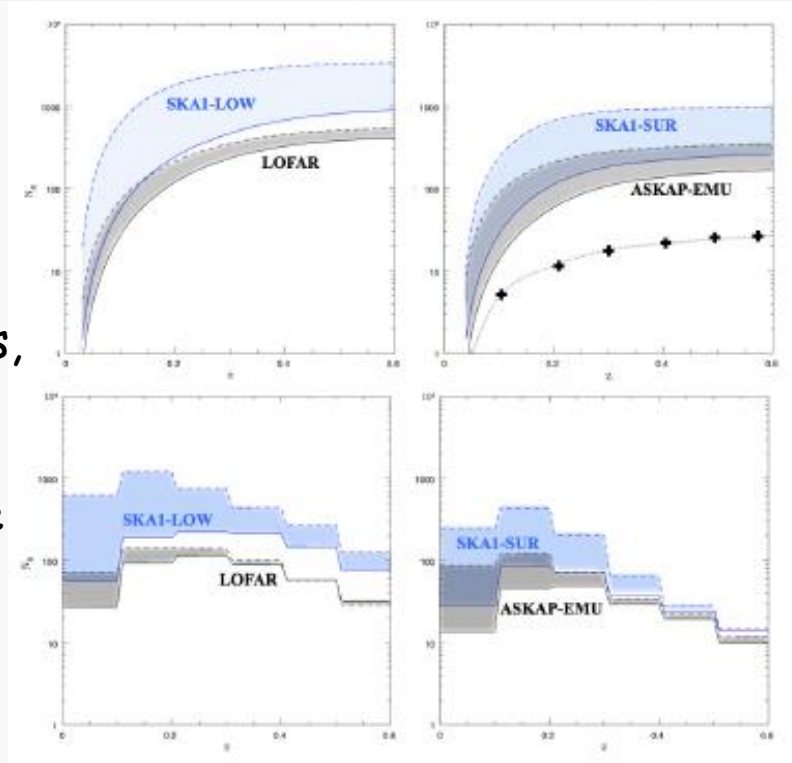


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Detection at high z ,
Statistical studies halos, relics,
minihalos

Correlations,
Link to cluster dynamical state
and parameters



Cassano et al.
2015

Thanks