SKA & The Plasma Universe

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Excellence Cluster Universe

with:
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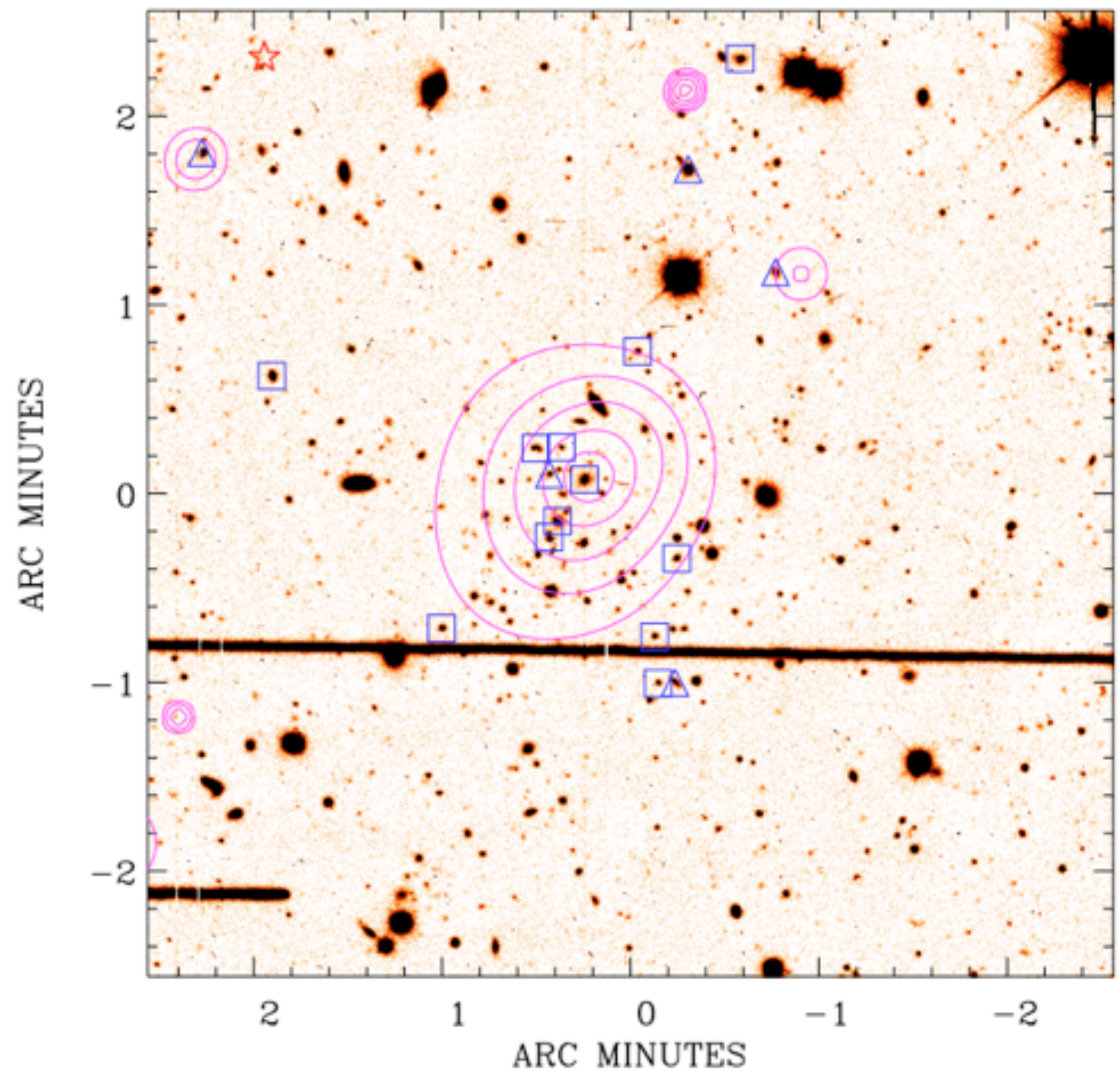
The Plasma Universe

- The vast majority of the Universe consists of plasma, i.e. charged particles & magnetic field
- Charged particles detected (e.g. X-rays) out to redshift z≈1
- Magnetic field poorly constrained, some details only locally , z<≈0.1



XMM-Newton detection of a galaxy cluster at z=0.8, Valtchanov et al. 2004

Some open questions

- Origin of magnetic fields:
  - Related to galactic outflows?
  - Exotic processes in the early Universe?
- Evolution of magnetic fields:
  - Dynamos & decay?
- Plasma effects:
  - Transport & confinement of heat & Cosmic Rays
  - Particle acceleration
  - Mixing of different phases of the Interstellar medium
  - Magnetic forces / energy content

This talk

- Cosmological magnetic field measurement predictions for SKA concepts
- Measurement of circum-radio source magnetic fields
- The plasma in radio galaxies

1. Evidence for magnetic fields

- Cosmological model / clusters
- Pol. srcs. based on S^3 predicted radio sky
- polarisations extrapolated / NVSS
- Faraday rotation of broadband images

Name	VLA[a]	SKA AA	SKA dishes	SKA dishes phase 1
$A_{\rm eff}/T_{\rm sys}$[b]	70–180	10 000	10 000	1200
Frequencies of interest (GHz)	0.3–0.34, 1.24–1.7, 4.5–5, 8.1–8.8	0.3–1	0.8–10	0.8–10
Instantaneous bandwidth (MHz)	86	700	250	250
1 h sensitivity (μJy)	17	0.18	0.29	2.5
Field of view (deg^2)[c]	$(0.7/f)^2$	250	2	20[d]

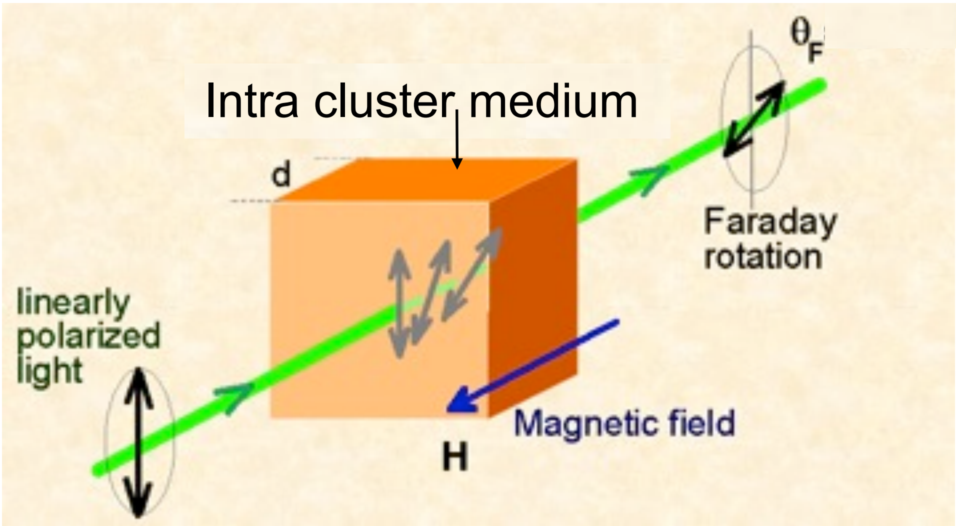
[a]See http://www.vla.nrao.edu/astro/guides/vlas/current/.
[b]Effective collecting area over system temperature.
[c]For the dish telescopes, given at the bottom of the frequency range; f denotes the observing frequency in GHz.
[d]Assuming phased array feeds.

Revision – Faraday Rotation

- Measure magnetic fields through Faraday rotation of plane of polarisation of light from background source. Rotation dependent on wavelength – measure rotation in several channels.
- Only gives line integral – B parallel to LOS.
- Requires electron density to be known (X-Ray).

$$RM = 812\int n_e B_{LOS} dl$$ Radians m^{-2}

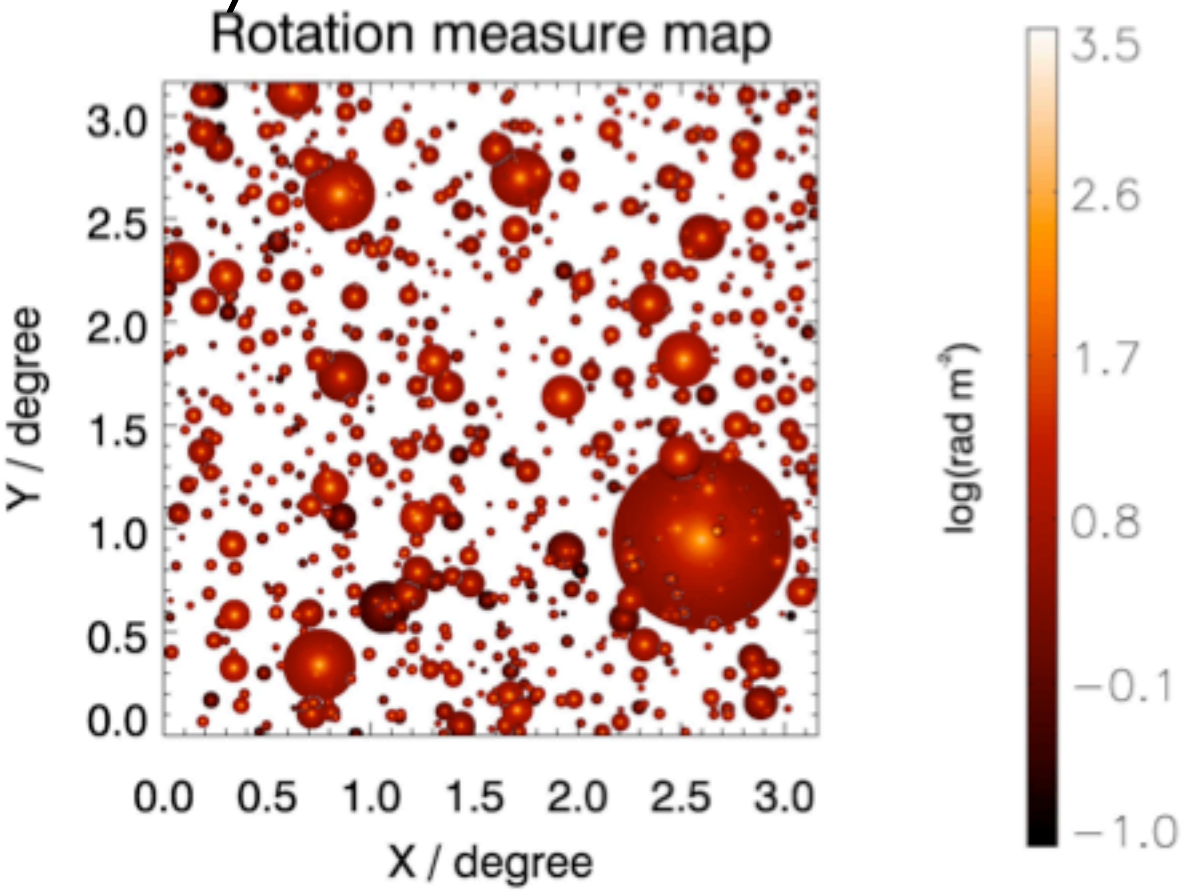
$$\Delta\vartheta = RM \times \lambda^2 / (1+z)^2$$



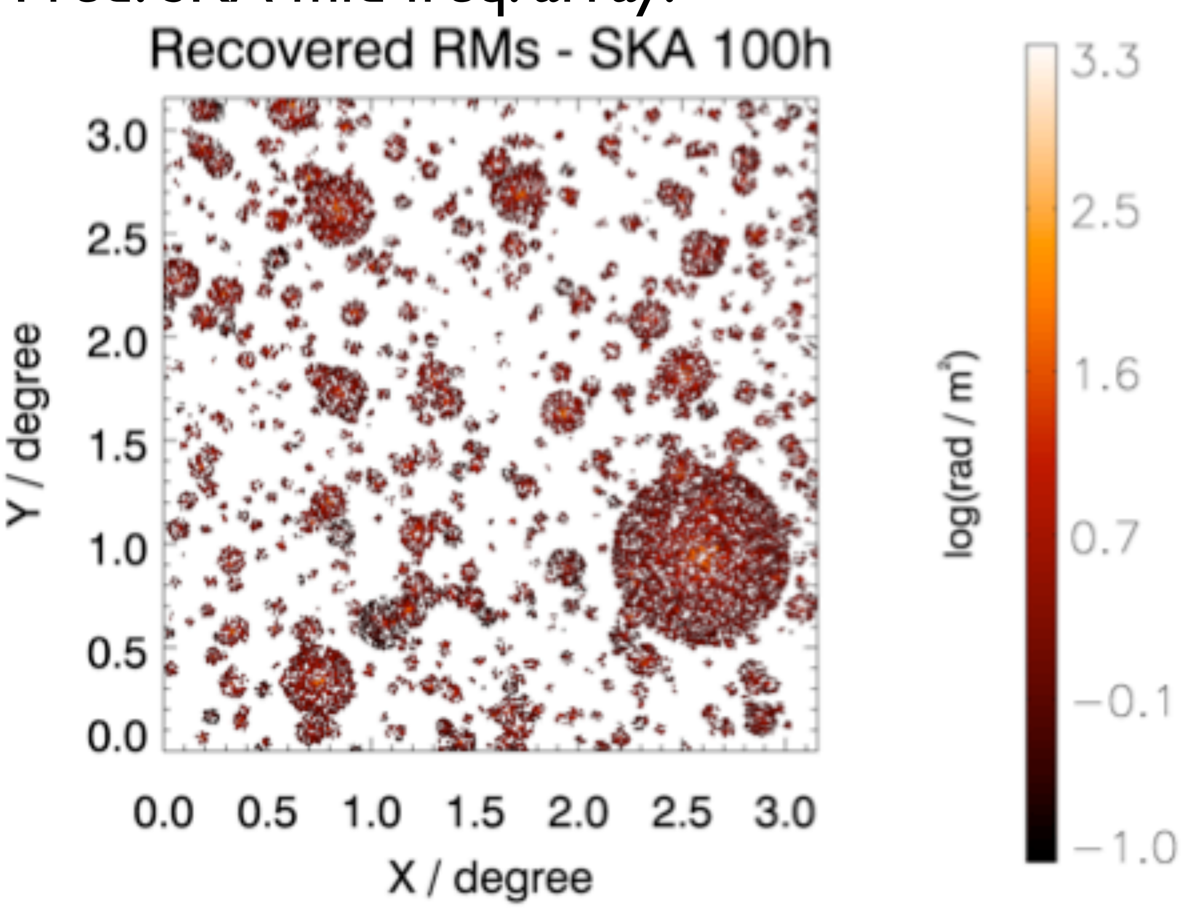
[Krause et al. 2009, MNRAS 400, 646]

Aperture Array (AA-hi)

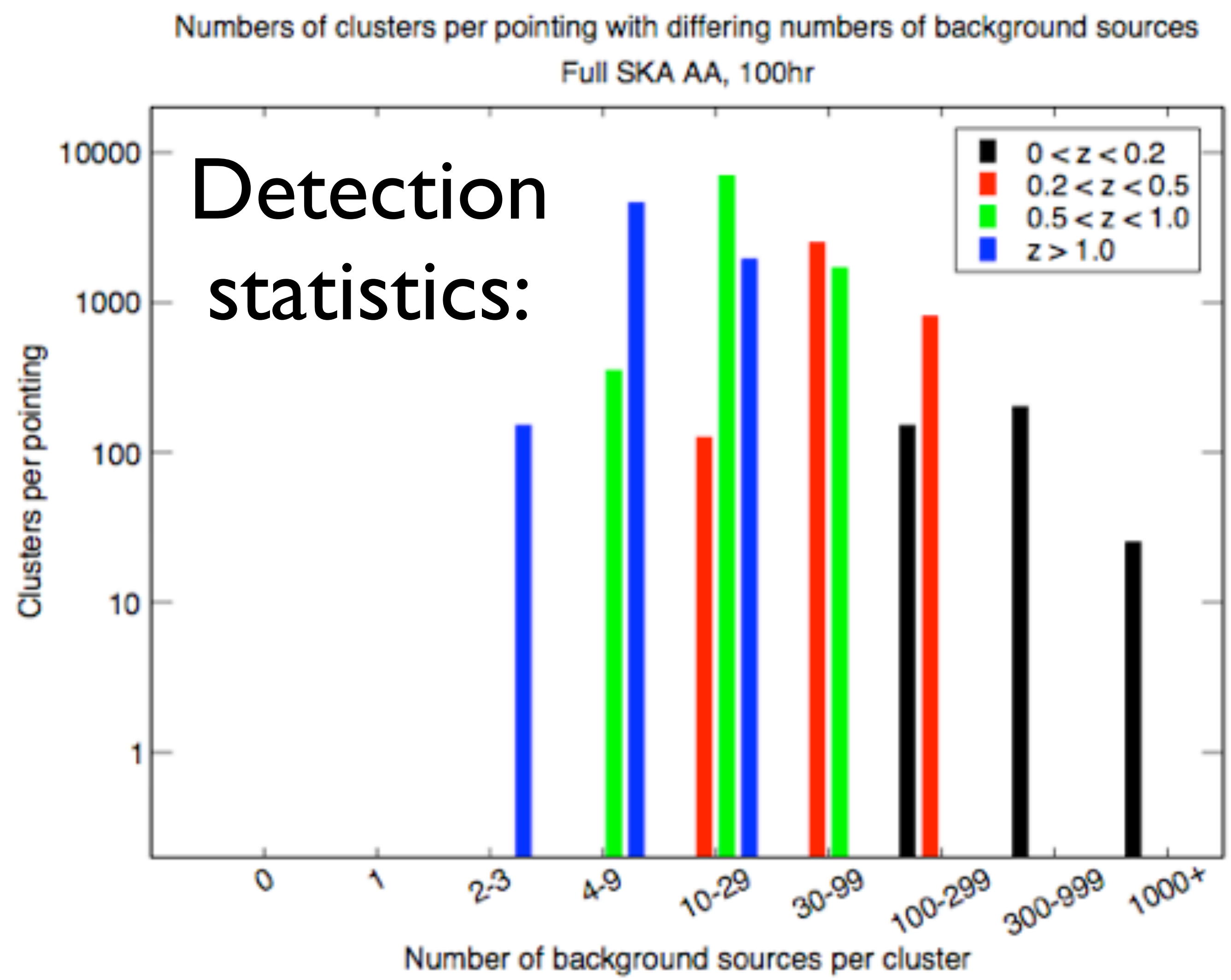
Semianalytic cosm. model.:



Pred. SKA mid freq. array:



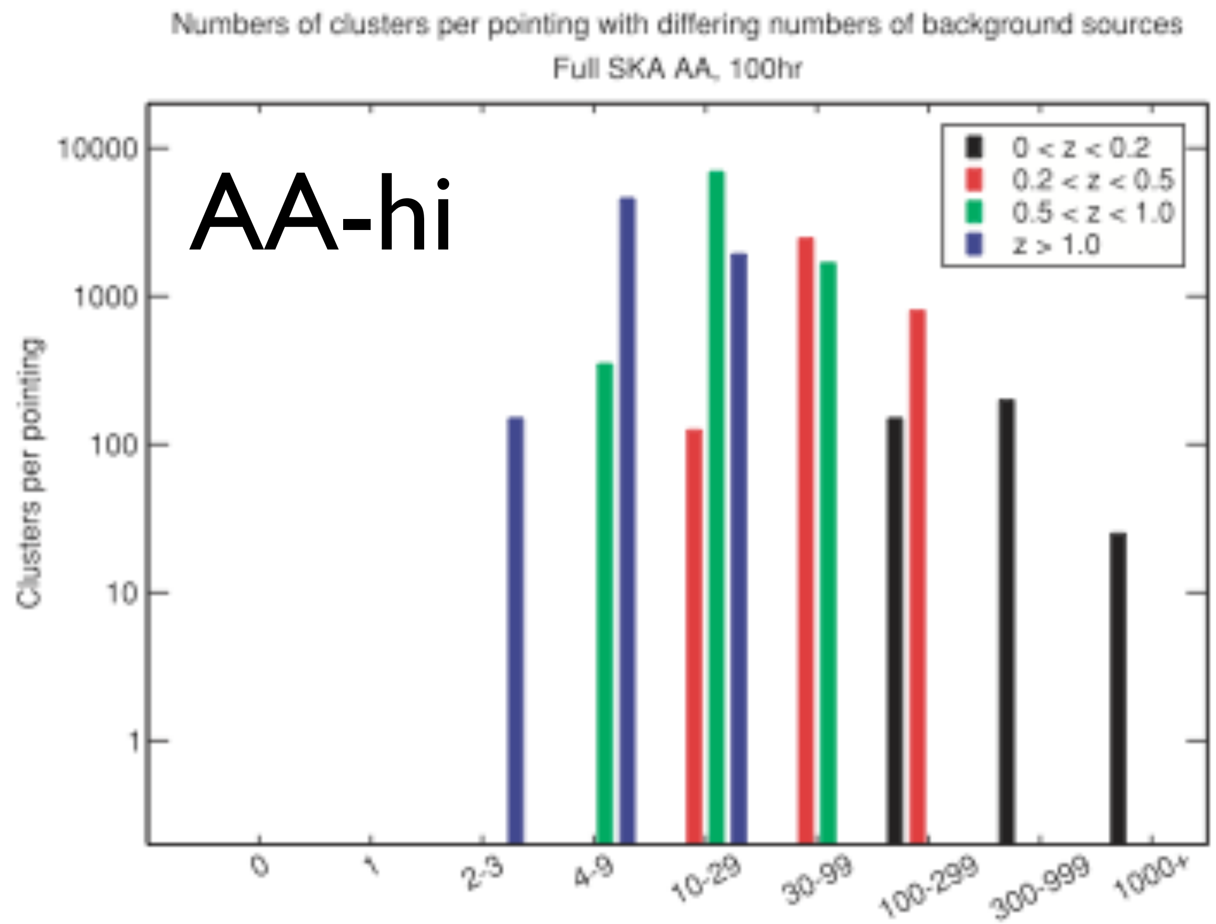
-count pol. background sources for each cluster
- Faraday rotation in 1000s of gal. clusters w. redshift > 1
- pol. srcs: mainly star forming galaxies, also high redshift

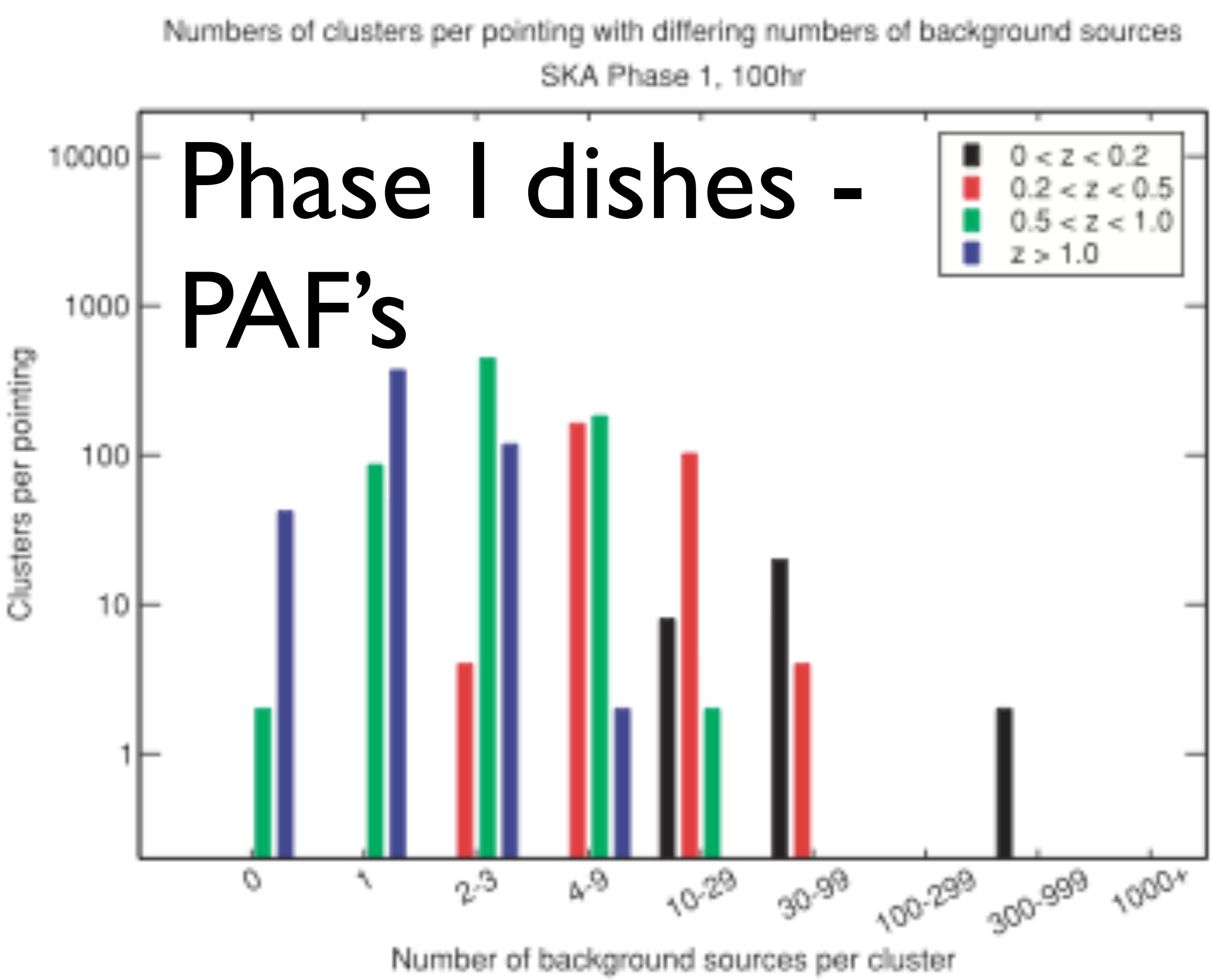


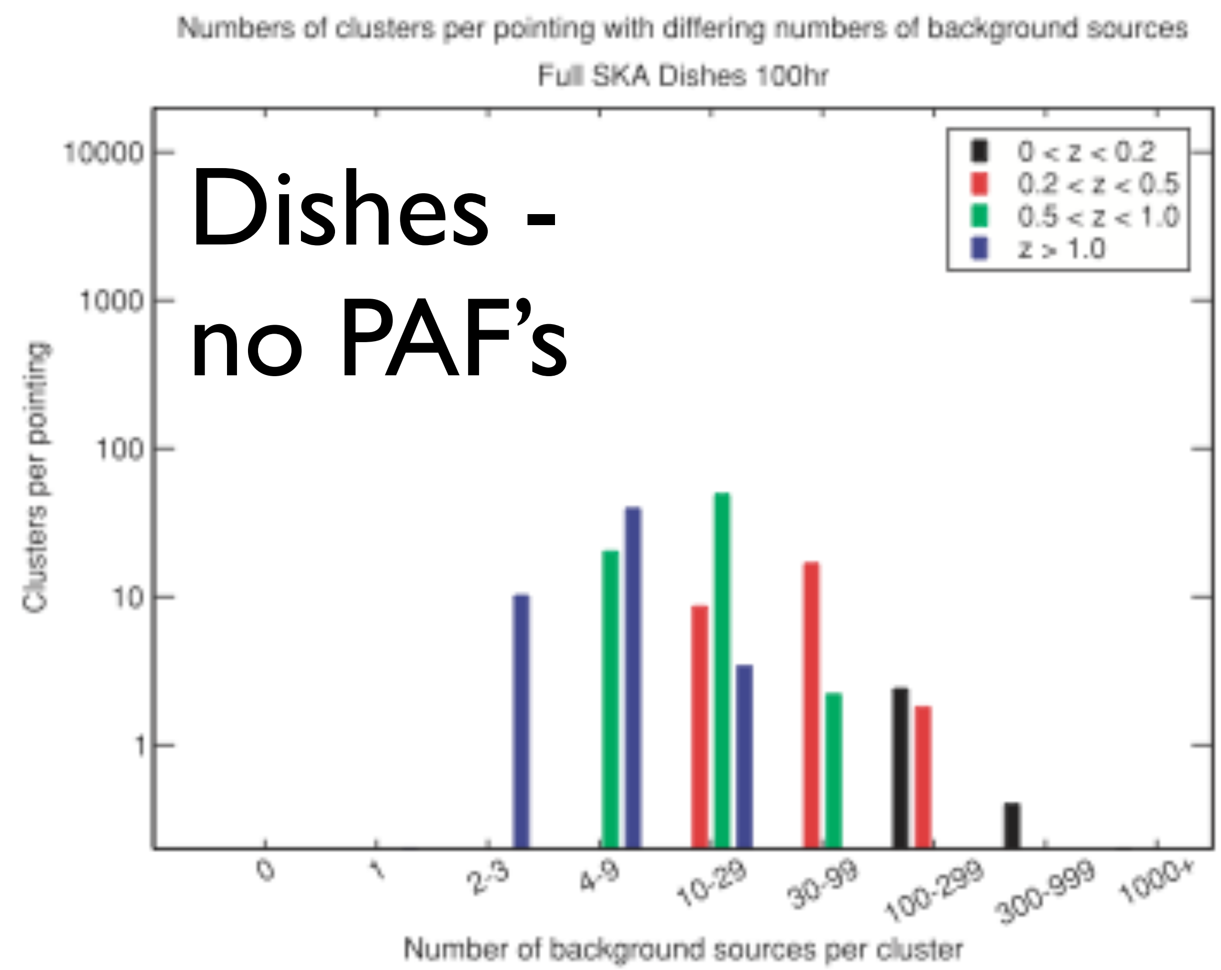
[Krause et al. 2009, MNRAS 400, 646]

Comparison SKA - concepts

- Aperture array or phased array feeds for survey
- Magnetic fields out to Z>1

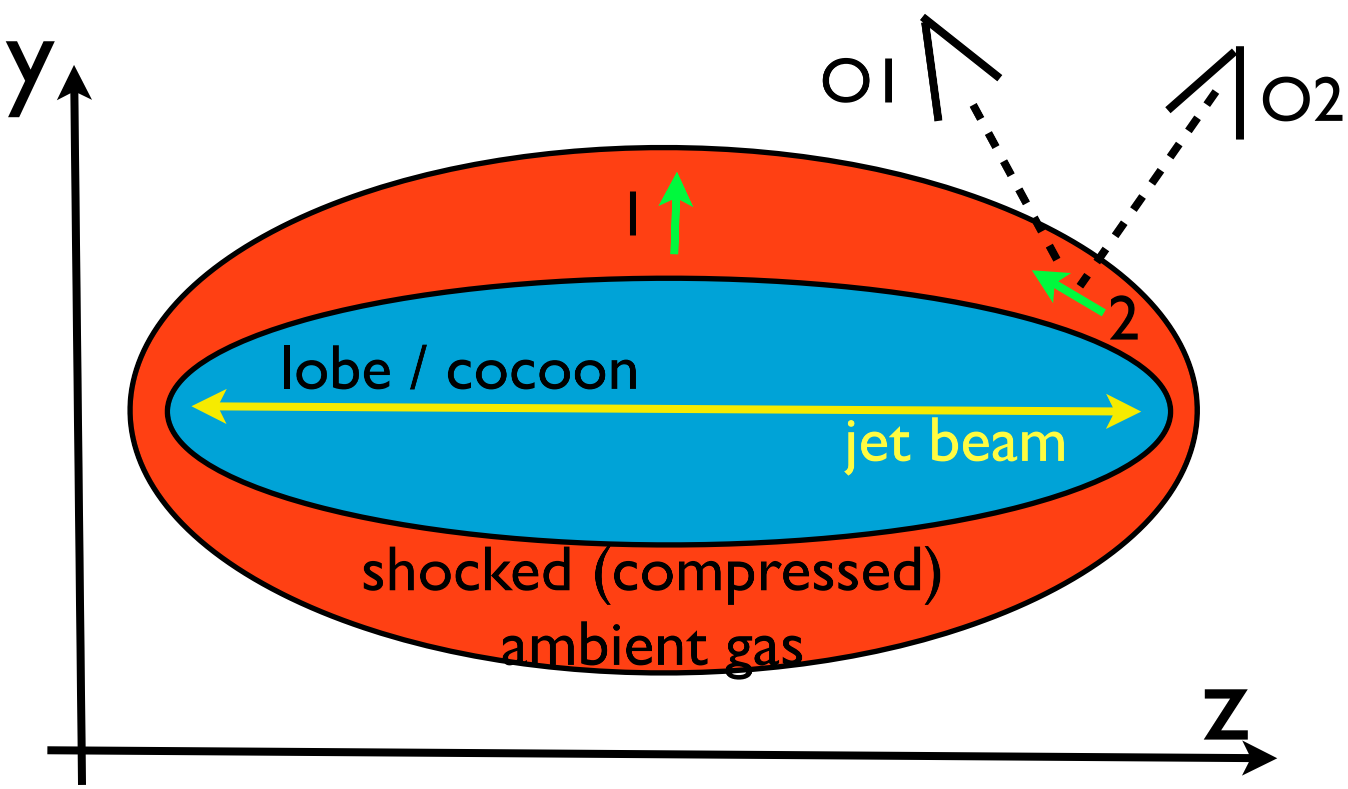


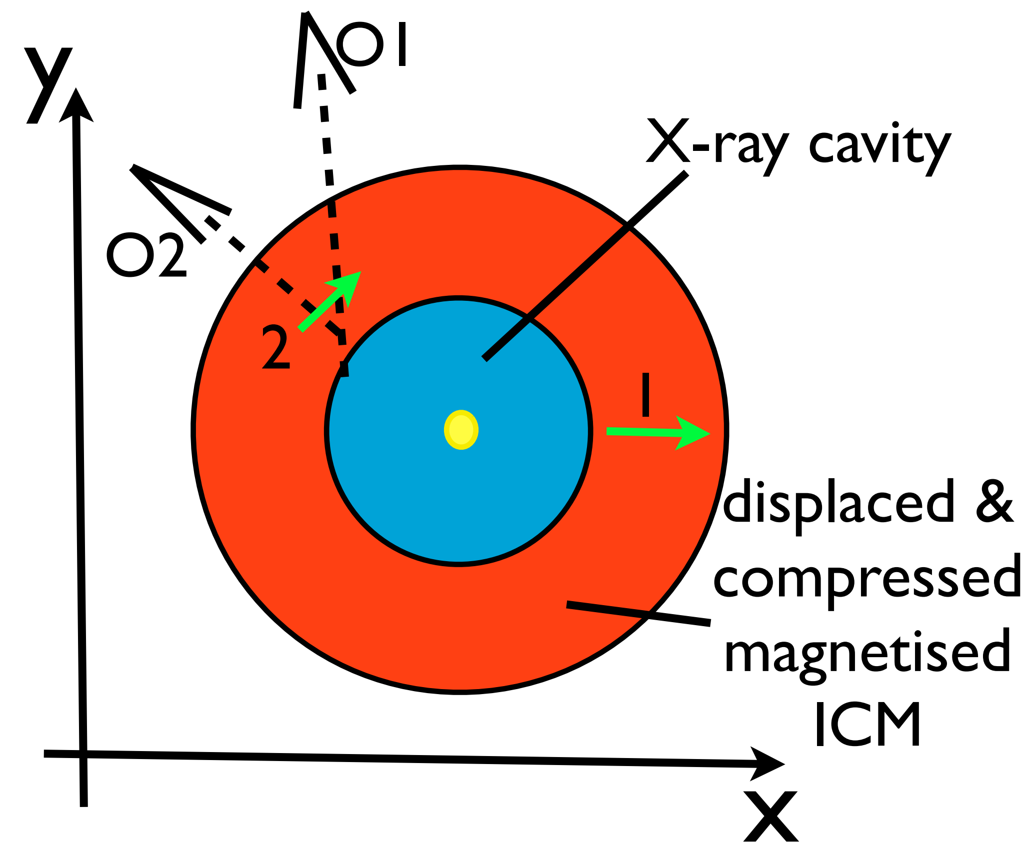




[Huarte-Espinosa, Krause & ALexander 2011b, MNRAS accepted]

Plasma around imbedded radio sources: local effects

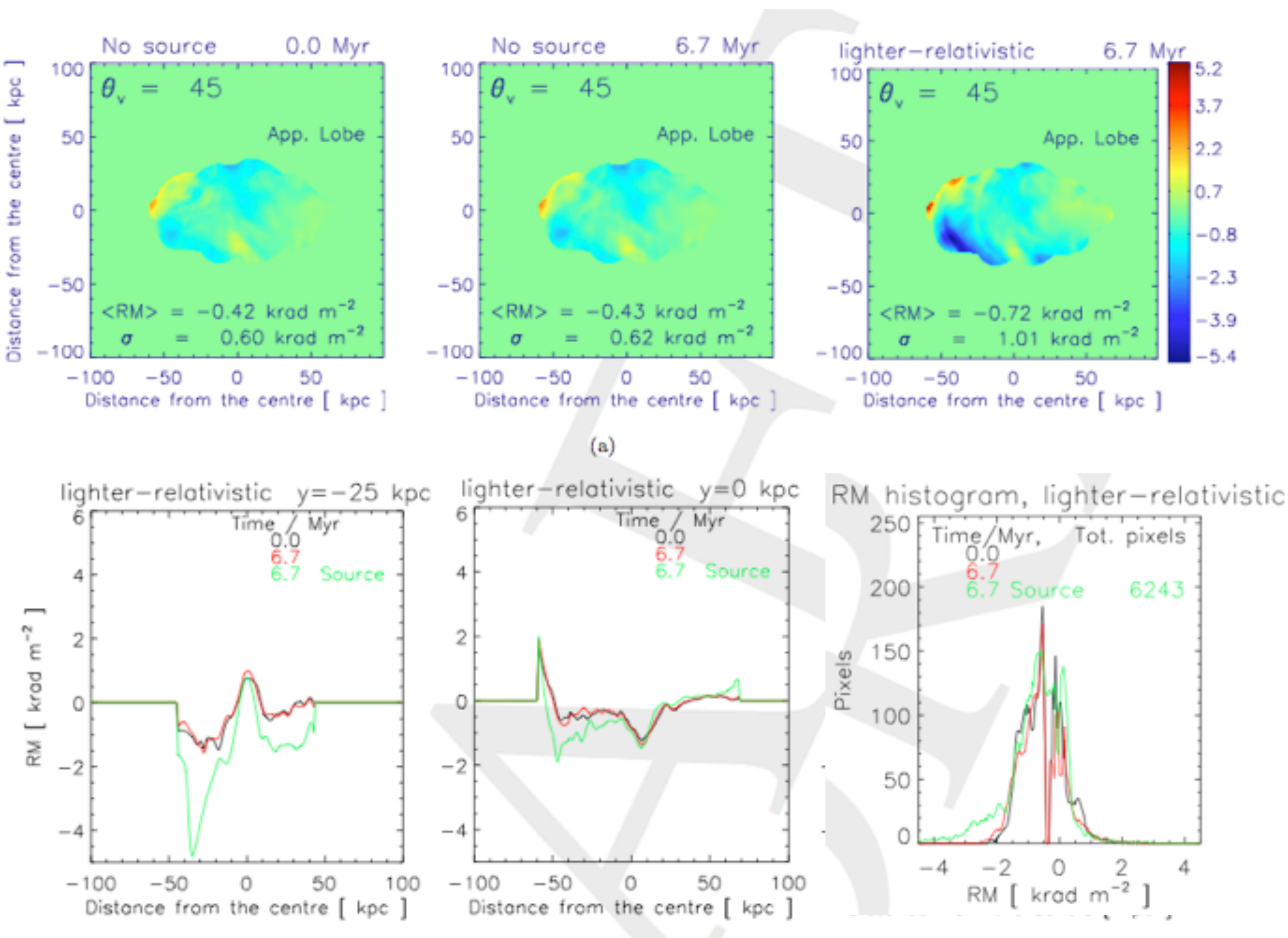




- Tangled field
- Non-radial component amplified by compression, expansion energy →MF
- If observer not ⊥ MF, RM enhanced
- RM-Enhancement for observer O1 => edge effect

Magnetic field vectors:
1 - radial
2 - non-radial

MHD jet-simulations with random cluster fields



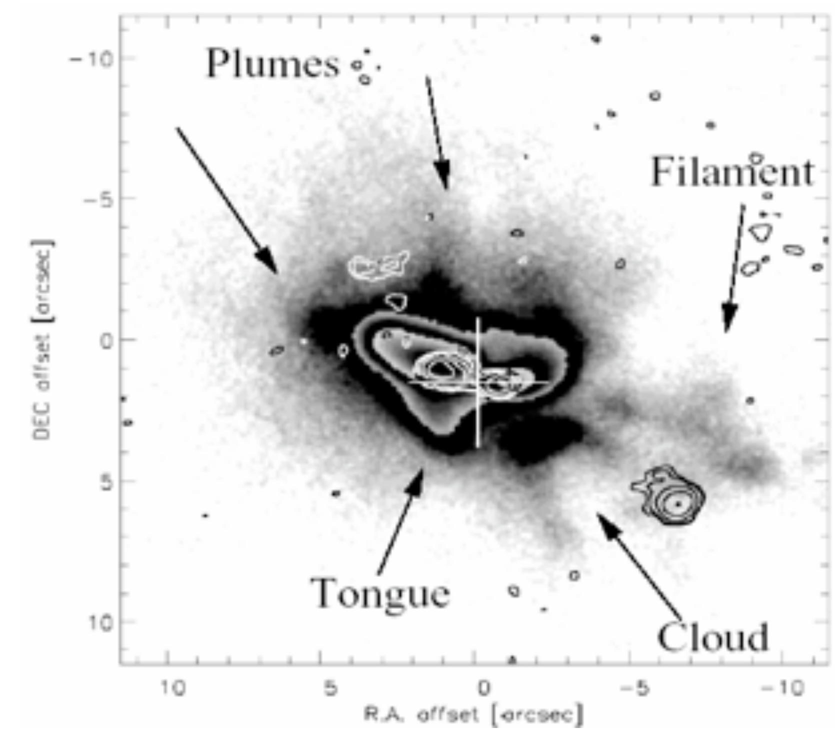
- up tp 70 % RM +
- edge enh.
- histograms changed @ high RMs
- lesser effect for high incl.

[Krause 2005, A&A, 436, 845]

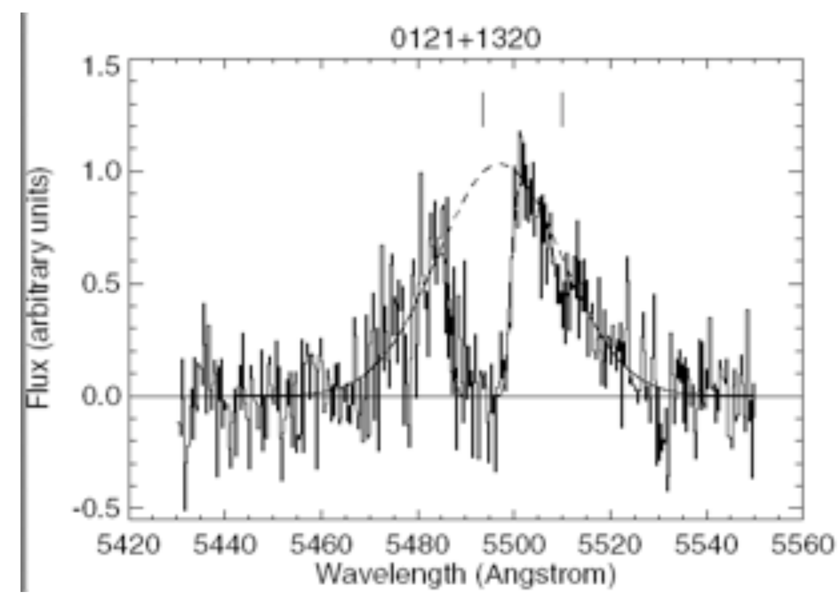
High redshift radio galaxies: surrounding gas compressed / wind shells

- Observation: emission lines from the smaller high redshift radio galaxies are absorbed on the blue wing
- Parameters: N=10^{18-20} cm^{-2}, v= -250 km/s, dv= 10-80 km/s
- Absorbers are similar to ones interpreted as galactic winds
- Suggestion: absorption by galactic wind shell, destroyed by jet impact

Ly α haloe of 4C 41.17 at z=3.8



Reuland et al. 2003



van Ojik et al. 1997

Blue wing self absorption

Faraday effect in high redshift (≈1-5) radio galaxies

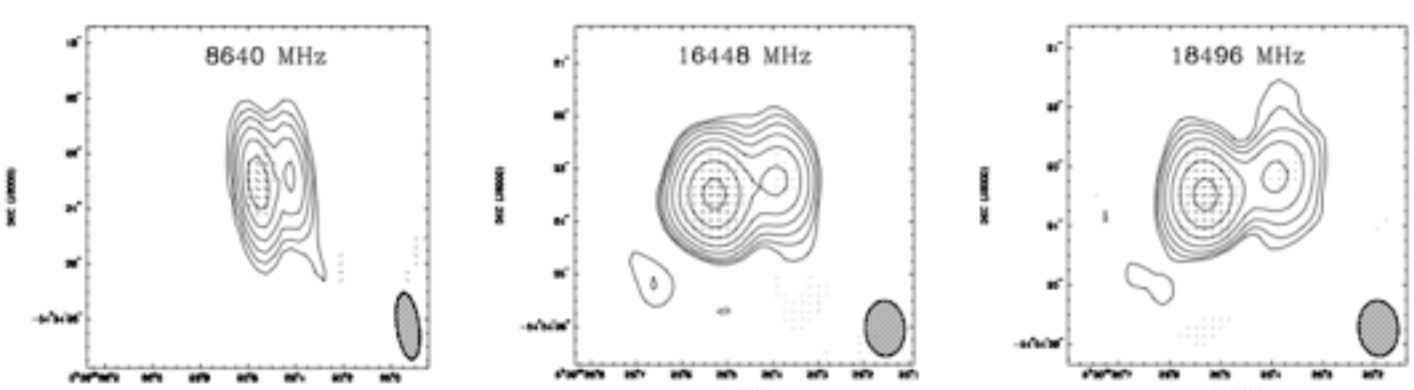
- 10s mJy (SKA: <μJy/1h)
- ≈1-10 arcsec (well resolved by SKA)
- edge enhancements? evidence for shell model

- spat. res. RMs: detailed plasma properties of local (to source) interstellar medium
- Faraday tomography of Lyman α halos → direct evidence for magnetised outflows? Mixing?

Mon. Not. R. Astron. Soc. **375,** 1059–1069 (2007) doi:10.1111/j.1:

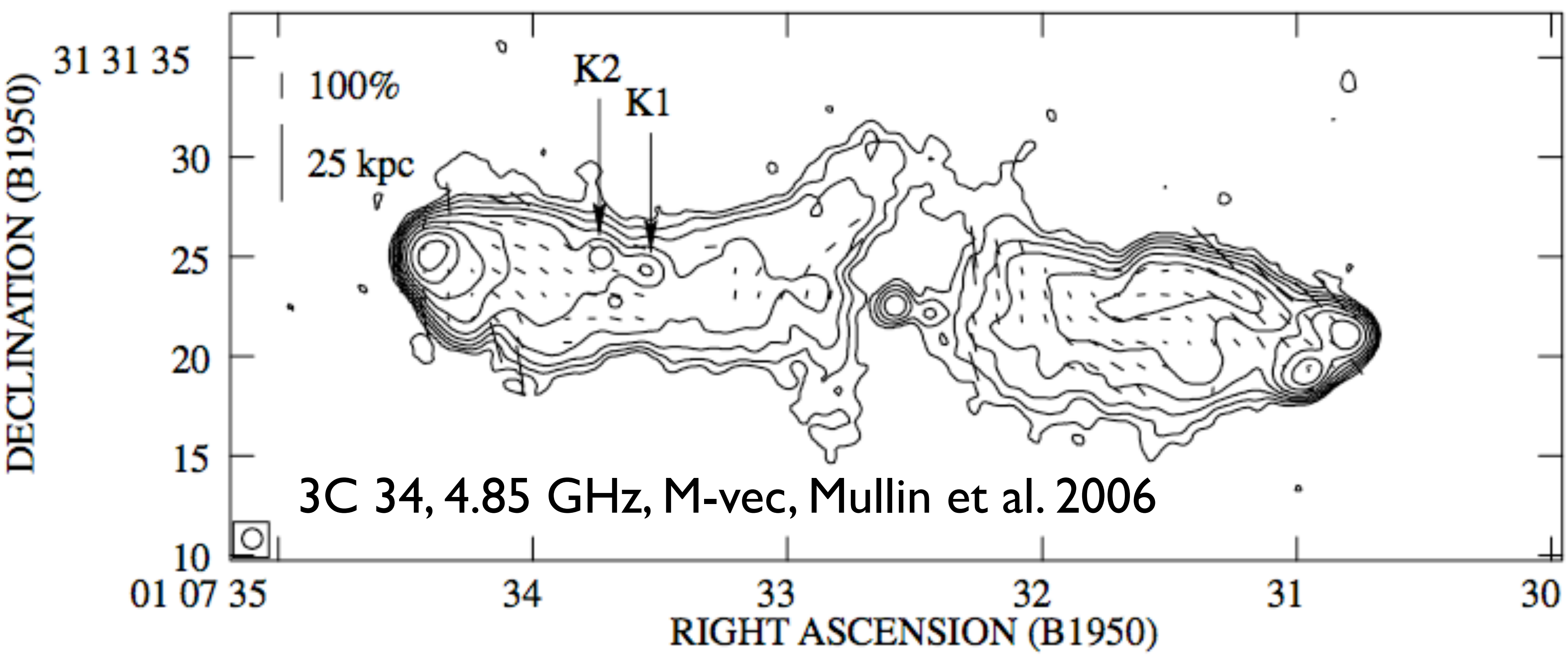
An extreme rotation measure in the high-redshift radio galaxy PKS B0529–549⋆

J. W. Broderick,[1]† C. De Breuck,[2] R. W. Hunstea



Plasma inside radio sources

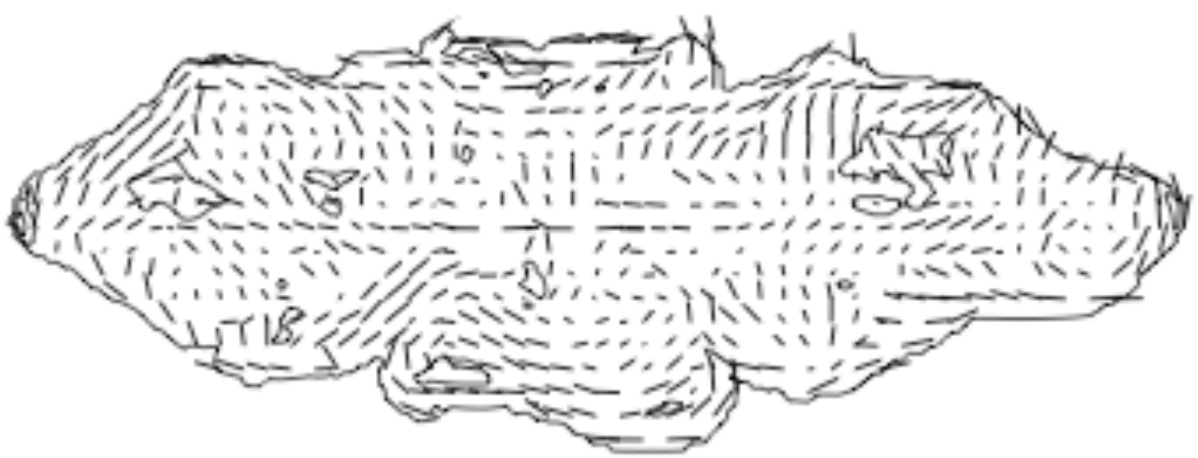
- non-thermal, (partly) relativistic, magnetised
- MHD (?), field configutation ?, confinement of Cosmic Rays / heat ?, boundary ?/ similar problem in fusion plasmas

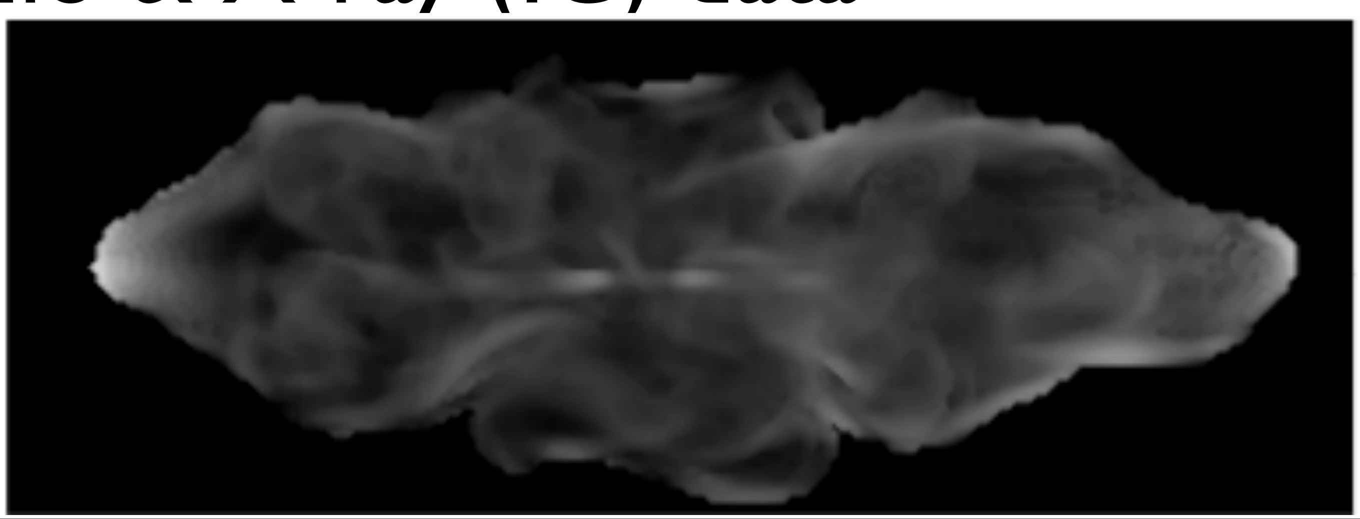


[Huarte-Espinosa, Krause & ALexander 2011a, MNRAS accepted]

3D MHD Simulated Polarisation

- Here, random init. jet field, dom. large scales
- Polarisation properties set by combination of cocoon turbulence & lobe expansion
- match frac. pol. ($\approx$50%)/ lower for lighter jets
- match orientation (||) / more || for heavier jets
- coc. boundary not treatable with MHD → confinement?
- Future: require better radio & X-ray (IC) data





Conclusions

- SKA will extend the magnetic horizon out to beyond redshift of unity, matching measurements of ionised particles (e.g. X-ray)
- Embedded sources/ winds compress magnetic fields
  - Advantage SKA: background sources
  - SKA should be able to resolve ISM around HZRG
- Plasma physics of closer Radio Galaxies: improvements by radio & X-ray missions