

Cosmic Magnetic fields and the SKA

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Outline

- Background
- Intergalactic field: feedback
- Measurement: statistics
- Current status
- SKA
- What will we learn?

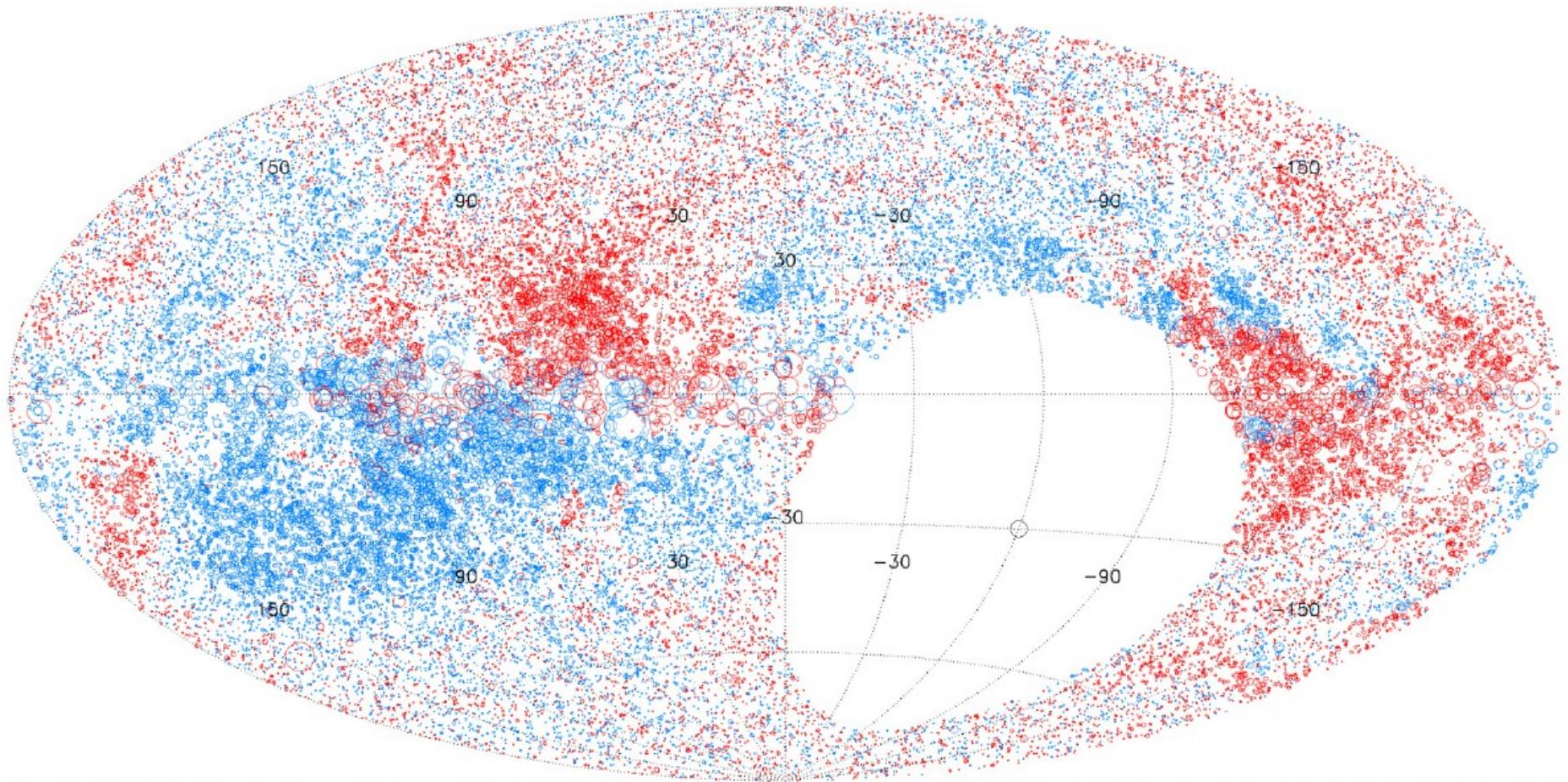
Cosmic Mysteries

- Dark Energy: precision BAO (SKA and others, c.f. Abdalla talk)
- Dark Matter: lensing (SKA: spec z, magnification lensing)
- Baryons: 95% are missing (hot IGM?)
- Energy: feedback, magnetic fields, galaxy formation

Magnetic Fields: observations

- Rotation Measure:
$$\text{RM} = \frac{e^3}{2\pi m^2 c^4} \int_0^d n_e B \, ds,$$
- Changes apparent polarization angle with frequency
- Due to birefringence of magnetized plasma
- Typical effect: ~ 1 rad/octave @ 1 GHz, good for L-band

Taylor, Stil & Sundrum 2009



ROTATION MEASURE IMAGE OF THE SKY

Figure 3. Plot of 37,543 RM values over the sky north of $\delta = -40^\circ$. Red circles are positive rotation measure and blue circles are negative. The size of the circle scales linearly with magnitude of rotation measure.

- Reanalysis of NVSS: 40,000 RMs

Accounting

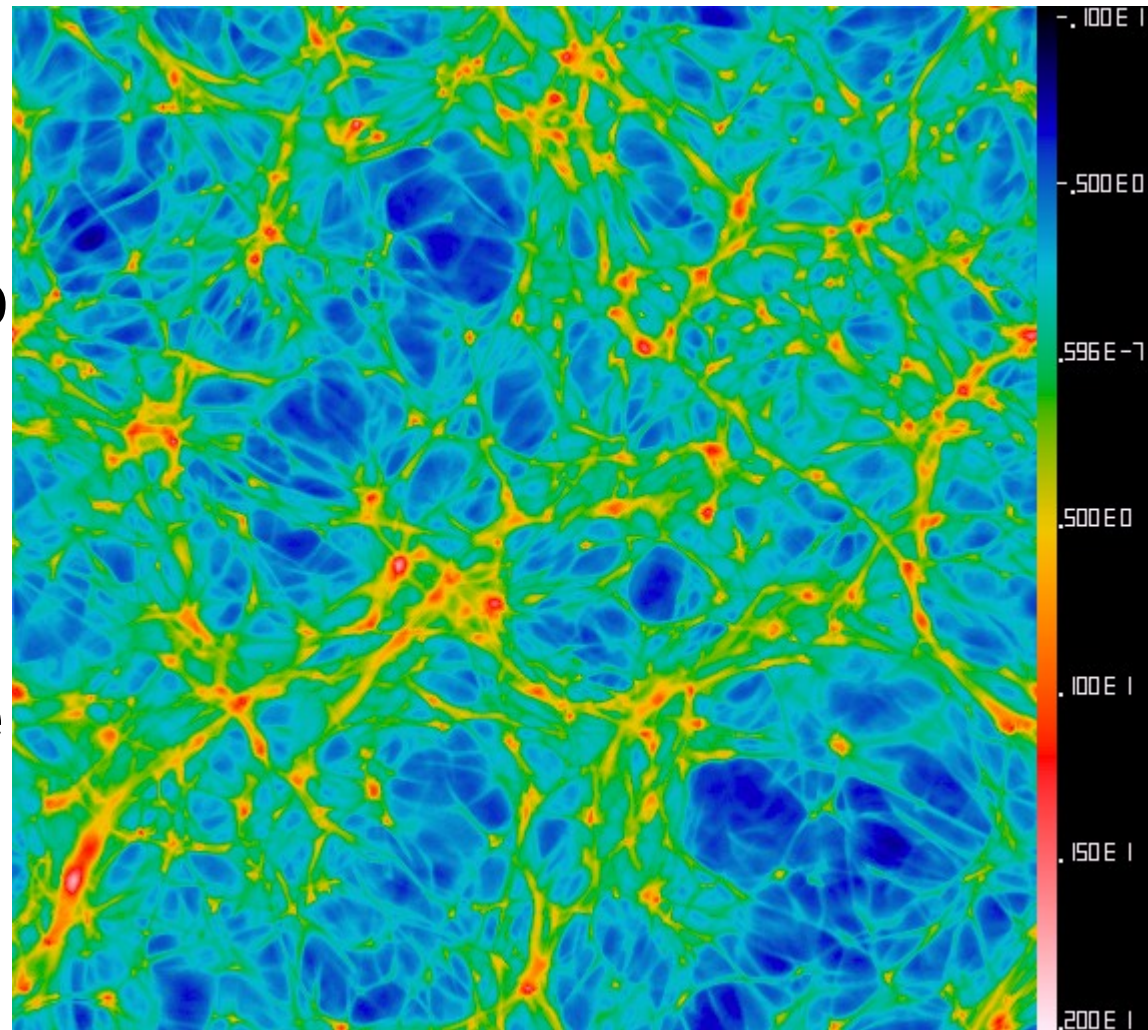
- Typical observed $|RM| \sim 30$, dominated by galaxy
- Galactic field is smooth, can be subtracted
- Intrinsic RM of sources, intergalactic propagation
- Primordial reionized IGM cannot have substantial magnetic fields, all fields formed in galaxies

Magnetic Expectation

- Need to know: B , r
- Max plausible B : equipartition $B^2 \sim nkT \sim$
micro Gauss
- Resistive expectation: 10 orders of magnitude
smaller
- Dynamos: work on small scales
- Max plausible r : 5 Mpc (feedback scale)

The IGM

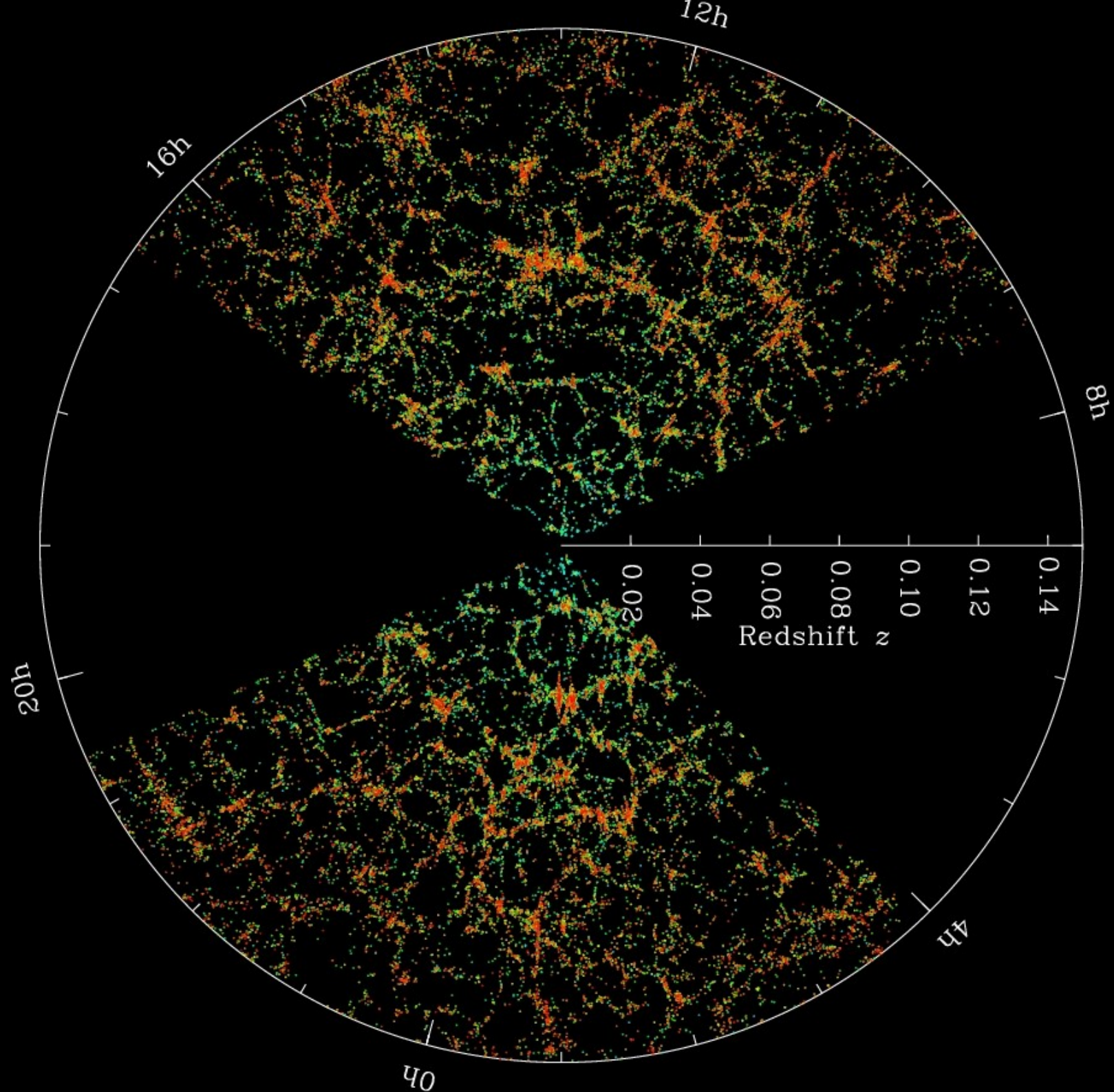
- Reservoir for the majority of baryons
- Feedback heated to ~ 1 keV (Pen 1999)
- Typical feedback radius > 1 Mpc, \sim degree scale on the sky
- Likely to carry magnetic fields



70 Mpc, Pen 1998

Confusion

- B is intrinsically 3-D, but observed in projection
- Confusion from galaxy, intrinsic, and other LSS
- Typical line of sight contributes $RM \sim 1$, small compared to galactic and intrinsic, and an integral over redshift
- Requires statistical comparison to other tracers



M. Blanton,
SDSS

Cross Correlation

- Optical (or radio) redshifts
- Discrete origin: neighboring galaxies have magnetic fields, galaxy-galaxy correlation will result in magnetic correlation $\sim r^{-3.6}$
- Feedback would have flat correlation, then sharp drop off after correlation length
- Some nearby nvss sources would physically correlate with SDSS galaxies, $\sim r^{-1.8}$

Current Status

- SDSS-NVSS RM
- 40 million photo-z galaxies, 7244 radio RM.
- Lee et al, arxiv:0906.1631
- Can be interpreted as 30 nG fields over 1 Mpc, or correlation c NVSS noise and SDSS systematics

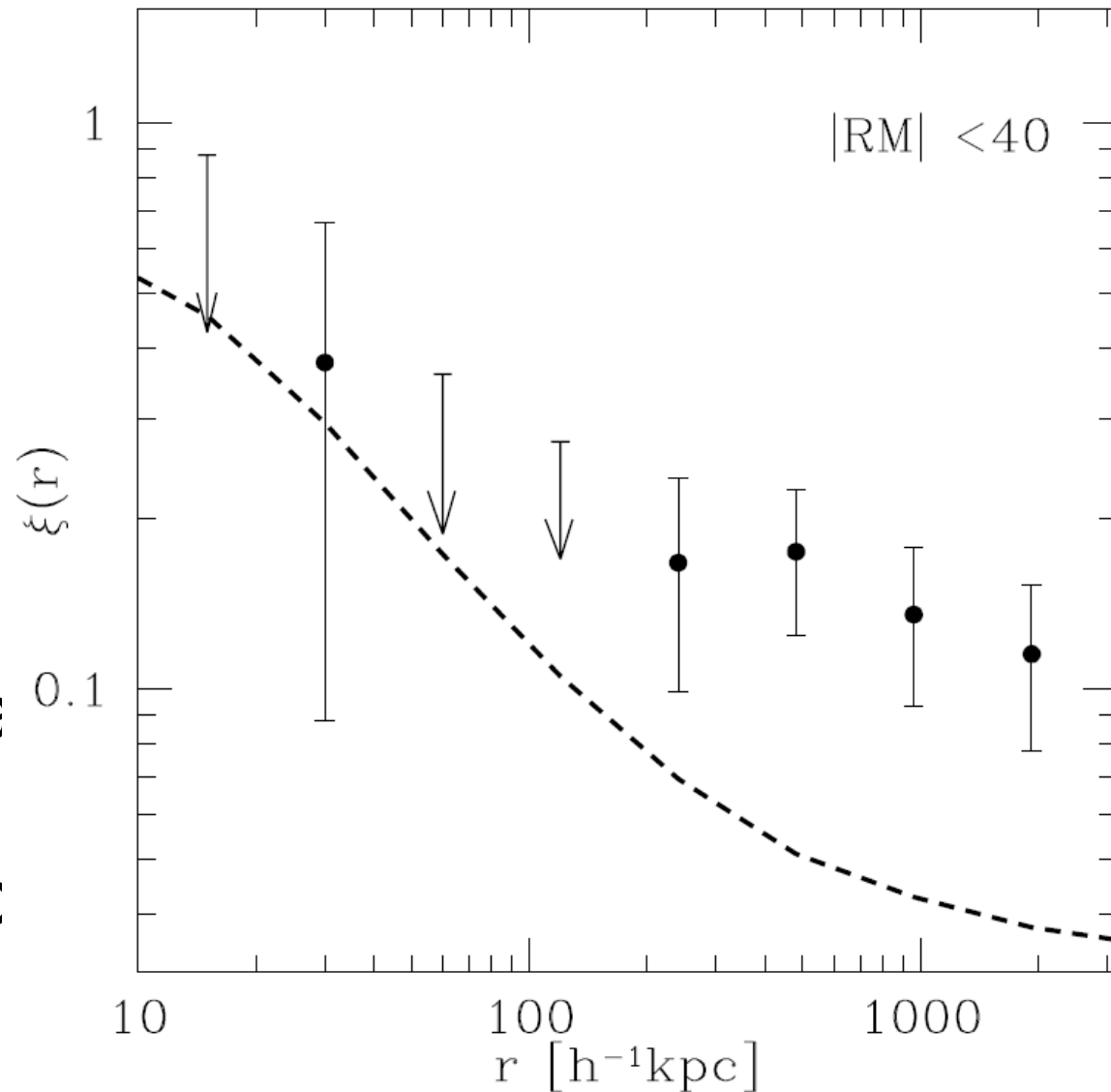


Fig. 3.— Same as Figure 2 but only for those radio sources with $|RM| \leq 40$.

SKA

- Combine LSST & SKA, or use 21cm redshifts
- 10 RM/sq arc min, many more optical photo-z sources: billion RM and even more photo-z on the sky
- Potentially possible to make 3-D RM map if source z are known
- Any 3-D map will not have resolution on the B coherence scale: still statistical
- Measure cross correlation and time evolution: evolution of IGM
- Complementary with S-Z measurements of IGM

What might we see?

- At early times after reionization ($4 < z < 10$), only fields in galaxies
- As galaxies form and feedback, magnetic flux will be expelled, IGM contaminated by B and Z.
- Filling factor of feedback will increase, overlap at $z \sim 1$? (decline in QSO, star formation)
- Probed by RM cross correlations
- Properties of IGM are necessary input to understand galaxy formation

Conclusion

- Rotation Measures are potentially powerful tools to probe the evolution of the intergalactic medium.
- Substantial room for progress with current instruments (GMRT, EVLA, ATCA)
- RM: last year, 10^3 , this year $10^{4.5}$ known, 10^6 achievable pre-SKA, 10^9 with SKA
- SKA will measure the full quantitative evolution of IGM, feedback parameters.