Probing Galaxy Interactions via Spectropolarimetry

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- Galaxy Groups
- Rotation Measure Synthesis/Spectropolarimetry
- The bigger issue: calibrating the Giant Metrewave Radio Telescope
- Some results
- Summary
Holmberg 124 - Kantharia et al., 2008
Linear polarisation directly reveals regular magnetic fields. Such fields could be enhanced by tidal interactions or ram pressure from the intergalactic medium (IGM) compressing the $B$ field of the galaxies. Can polarised ridges be detected in known interacting galaxies?

Observed the Grus Quartet & USCG S063 - two galaxy groups from the Southern Compact Groups sample. Both groups have extended tidal tails, and a perturbed gas distribution - good candidates to look for interactions with the IGM.

Observed with the GMRT to a sensitivity of 36$\mu$Jy/beam in full-polarisation at 610 MHz.

Want to use one of the best tools for detecting $B$ fields: Spectropolarimetry!
\[ \chi = \chi_0 + \phi \lambda^2, \] 

\[ \phi \propto \int_{\text{telescope}} \int_{\text{source}} n_e B \cdot dl, \]
Express the observed linear polarisation vector as an exponential:

\[ P = Q + iU = p_0 \cos 2\chi + ip_0 \sin 2\chi = p_0 e^{2i\chi} \]

By integrating over all Faraday Depths:

\[ P(\lambda^2) = \int_{-\infty}^{+\infty} F(\phi) e^{2i\phi\lambda^2} \, d\phi, \quad F(\phi) = \int_{-\infty}^{+\infty} P(\lambda^2) e^{-2i\phi\lambda^2} \, d\lambda^2. \]

Where \( P(\lambda^2) \) is the complex observed polarisation, and \( F(\phi) \) is the “Faraday Disperson Function” which describes the intrinsic polarisation at each Faraday depth.

Everything on the RHS is observable! But is a sum including negative \( \lambda^2 \)!

\[ F(\phi) \approx K \sum_{i=1}^{N} W_i P_i e^{-2i\phi(\lambda_i^2 - \lambda_0^2)} \]
Spectropolarimetry is already, or will soon be, feasible at a number of radio facilities:

- JVLA
- LOFAR
- ASKAP
- Arecibo
- ATCA
- MWA
- Parkes
- GMRT
The GMRT

- 5 observing bands at 150 MHz, 235 MHz, 325 MHz, 610 MHz and 1.4 GHz
- 30x 45m dishes – collecting area of ~50,000 m² with Tsys ~ 102K @ 610 MHz = 2.5% SKA
- Observe in spectral line mode with software correlator (512 channels across 32 MHz) - helps with the RFI environment
- Maximum baseline of 27 km = resolution ~5” at 610 MHz
- Full-polar observations (RR, LL, RL, LR) online since late 2008 - initially on an experimental basis - had to commission, calibrate, and test in order to create a pipeline for polarimetric data. Many systematics...
  - Calculating instrumental polarisation, time-variability of the instrumental polarisation, applying corrections to the uv-data, ionospheric Faraday rotation, electric vector polarisation angle corrections across the observing bandwidth.
- Relatively wide field of view, FWHM = 0.75° at 610 MHz (wide-field polarimetry).
Polarised Intensity

(Jy/beam)

2×10^{-3}  4×10^{-3}  6×10^{-3}  8×10^{-3}  0.01  0.012

J2000 Declination

J2000 Right Ascension
\[ R = \sum_{i=1}^{k} I_i(x, y) \{ Q(x', y') + iU(x', y') \} e^{2i\chi} \equiv \begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos \chi & \sin \chi \\ -\sin \chi & \cos \chi \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \]
\( \alpha = 0.57 \pm 0.13 \)

X-shaped radio source
FR-I class.

Large-scale change of sign of the magnetic field in the jet relative to the nucleus.
Setting up an instrument for wide-field spectropolarimetry at low radio frequencies requires many systematics to be dealt with, but crucial for understanding cosmic magnetism.

Some initial probes of galaxy interactions with the GMRT find a number of interesting sources, and make useful measurements of the group members’ spectral index, polarisation fraction, and Faraday dispersion function.

BUT we find no evidence for interaction with the IGM in either group:

- Either tidal interactions or ram pressure from the IGM does not significantly compress the magnetic field of these group galaxies,

- Or a substantial improvement in sensitivity is still required to probe galaxy interactions via polarimetry at low frequencies (Faraday depolarisation likely significant for our limited sample).
The GMRT can now be used for µJy level full-polarisation radio surveys at low frequencies with a large field of view – a new tool to probe magnetic fields.

Multiple new facilities about to observe the magnetic Universe at a range of frequencies:
- LOFAR @ <230 MHz
- JVLA @ > 1.2 GHz
- ASKAP @ 700 MHz – 1.8 GHz
- GALFACTS (Arecibo) @ 1.2 GHz – 1.5 GHz

A GMRT upgrade is underway – likely to provide nearly seamless frequency coverage from 50 MHz – 1.5 GHz with instantaneous bandwidths of 400 MHz. Centred within an important observational void of the SKA pathfinders...
Thanks for listening!