The Intricacy of the Spiderweb

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Introduction

The "Spiderweb Galaxy" is a massive irregular radio galaxy located inside a dense and dynamic environment at z = 2.16 (10.7 Gyr look-back time). It probably represents a precursor of modern-day cD-type galaxies, sitting inside the precursor of a modern-day massive galaxy cluster. It therefore provides a window in to the distant past of these systems, which drive the evolution and ecology of the cosmos.

Previous studies[1,2] have reported extreme source-frame Faraday rotation measure (RM) values of ~6000 rad/m^2 in the system, providing evidence of a massive reservoir of magnetized and ionized cluster gas, and the opportunity to study mass assembly and AGN feedback in the early Universe.

This work builds on that discovery. We present preliminary analysis and results from a new broadband, full polarization Jansky VLA study of the Spiderweb system.

A remarkable target for the broadband era

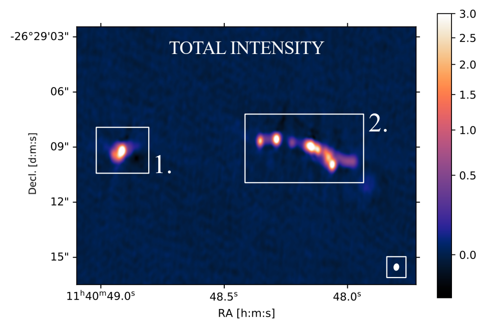
Broadband correlators have revolutionized astronomical radio polarimetry over the past decade[3]. When compared to older narrowband systems, they provide:

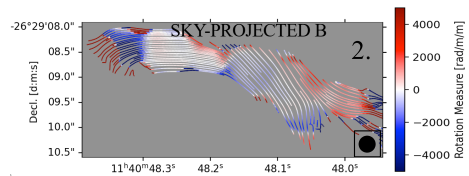
- Far greater raw sensitivity to polarized emission, especially after coherent summation across the band by techniques like RM synthesis
- The ability to simultaneously model Faraday rotation and de/re-polarization, which provides far richer information about magneto-ionic structure along the line of sight
- The ability to correct to the source-frame for high redshift sources, while simultaneously maintaining comparatively broad wavelength-squared coverage in the source frame

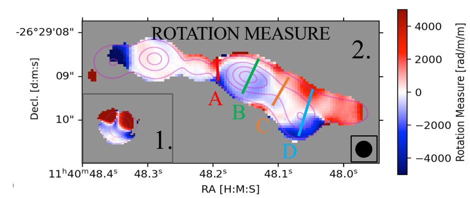
We observed the Spiderweb system over 8—2 and 29—37 GHz with the Jansky VLA, reaching a full-band sensitivity of ~ 5 nJy/beam per Stokes parameter, and we are now analyzing these data with modern techniques such as QU-fitting and RM synthesis.

Results: The best-ever B-field map of a high-z radio source

Our main preliminary result is the best-ever spatially-resolved Faraday RM map, and magnetic field orientation map, of a high-z radio galaxy. The RM map shows smooth and significant changes in structure on kpc-scales, including high measured intrinsic RMs, a bifurcation in the jet's magnetic fields structure, and a possible transverse gradient along the length of the radio jet.

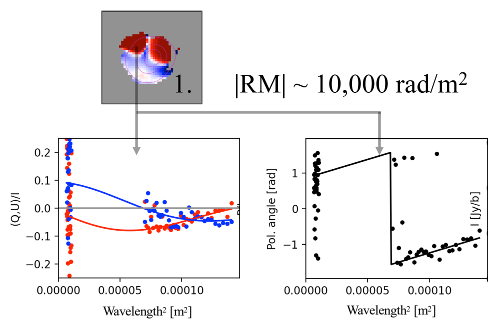






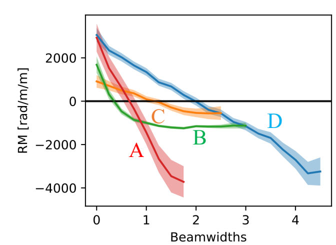
Results: High intrinsic RMs confirmed, and extended

We confirm the the presence of extreme rest-frame RMs, and in fact measure higher values than previously reported (|RM|=10,000+/-500 rad/m^2). The RM varies by almost twice this magnitude over scales that are smaller than a polarized beam-width (~40 kpc).



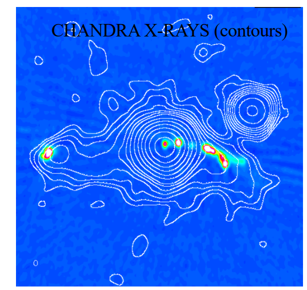
Results: A kpc-scale RM gradient across the jet?

The northern-most edge of the jet shows predominantly positive RMs, reversing sign across the main axis of the jet to become negative along the southernmost edge. Such 'zero-crossing' RM gradients imply a line-of-sight magnetic field reversal, and have been observed at both pc-scales[4,5] and kpc-scales[6] in radio jets many times before. They may be associated with helical magnetic fields in the jets. More generally, they suggest that the Faraday-active gas lies in the immediate vicinity of the jet, and that the RMs trace jet-gas interactions.



Adding X-ray (Chandra) data

Chandra X-ray data (in hand) traces the hot gas in the system. Preliminary maps show several interesting features, including extension and alignment of the X-ray emission along the jet axis (perhaps from inverse-Compton-scattering of low-energy photons), bright emission from the central AGN, and an extended halo, which is likely thermal emission from the hot proto-cluster gas. We aim to disentangle the latter from the former contributions, and to combine these measurements with our polarization modelling to measure the cluster magnetic field strength and structure, as well as the energetics, ages, and pressures of relativistic particle in this high-z system.



Outlook

Our analysis is ongoing. In addition to the above, we intend to search for ultra-high RMs in the 29—37 GHz data, and to understand how the detailed depolarization properties of the system can shed light on the structure of the medium around he source. Putting all of this together will give us a unique new picture of structure formation, and AGN feeding and feedback, in the high redshift universe.

References

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4. Asada et al. 2002, PASJ, 54, L39
5. Zavala + Taylor 2005, ApJ, 626, L73
6. Gabuzda et al. 2015 A&A 583, A96