Magnetisation of the IGM

Low Frequency Observations of the Dwarf Galaxy NGC1569

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Introduction

The origin of magnetic fields in the early universe has been a long-standing puzzle. How did magnetic fields originate in galaxies, from primordial ones or through the dynamo process? Is the intergalactic medium magnetized by outflows from galaxies? The possible magnetisation of the IGM by low-mass galaxies in the early universe had been proposed by Kronberg et al. (1999), followed by a more quantitative discussion by Bertone et al. (2006). The latter made predictions for the strengths of magnetic seed fields, which were amplified by large-scale dynamos over cosmic time. The two prime arguments for dwarf galaxies as agents (in competition with AGN) are:

- Large number, predicted in a ΛCDM cosmology, and observed as well
- Shallow gravitational potentials, rendering outflows of hot gas and relativistic plasma feasible.

In order to test whether relativistic particles and magnetic fields may leave the gravitational potentials of dwarf galaxies, we need to search for nonthermal radio continuum halos around dwarf galaxies that are, or have been in the recent past, vigorously star-forming.

One of the best candidates for performing this test located in the northern hemisphere is the well-known starburst dwarf galaxy NGC1569. It is

- Sufficiently nearby, at a distance of 3.36 Mpc.
- Characterised by a strong starburst that ceased 5 Myr ago, as inferred from a break in its overall synchrotron spectrum (Israel & de Bruyn 1988).
- Bright in the radio continuum such as to allow measurements with good sensitivity and resolution using the WSRT.

Previous Observations of NGC1569

The transport of a relativistic plasma out of this post-starburst galaxy is inferred from two observations (Kepley et al 2010). NGC1569 has a radio halo, extending out to about 2 kpc at 20 cm (see Fig. 1, left). Second, the projected orientation of its magnetic field as deduced from measurements of the linear radio polarisation is radial throughout (Fig. 1, right). This magnetic field is just dragged along with the wind, as the energy density of the wind is about 30 times that of the magnetic field.

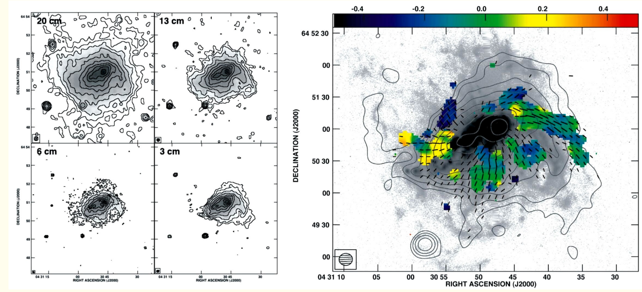

Fig. 1: Radio images of NGC1569. Left: Continuum maps at four wavelengths (VLA, WSRT). At 20 cm, the first contour is at 50 μJy/b.a. (3). Right: Magnetic field structure obtained at 3.6 cm (VLA), along with the rotation measure (colour wedge in units of 10^3 rad m^{-2}), superimposed onto an Hα image (from Kepley et al. 2010).

New Observations and a Sneak Peek at Some First Results

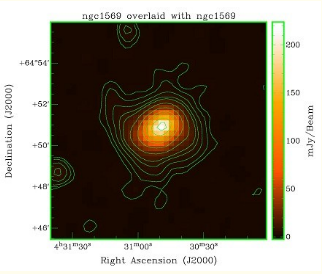

Fig. 2: Radio Continuum image of NGC1569 at 92 cm (WSRT).

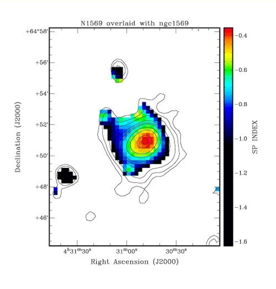

Fig. 3: Spectral Index map between 90 cm and 6 cm

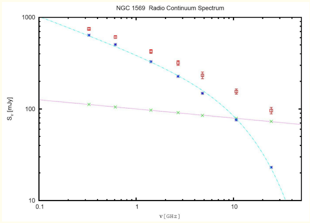

Fig. 4: Integrated radio continuum spectrum of NGC1569, with the most reliable data culled from the literature, and the new measurement at 327 MHz included. Shown are the total flux densities (red squares), the free-free radiation (green crosses), and the synchrotron fluxes (blue stars), the latter obtained by subtracting the thermal from the total fluxes.

We observed the radio continuum emission from **NGC1569** at **92 cm** with the **WSRT** for **12 hrs** in the **maxi-short** configuration. The IVC/DZB was employed with 128 channels, 4 polarisations, 8 bands and 10 MHz bandwidth. The maximum spatial resolution is 55" in the EW direction and 110" in the NS direction. The dataset was calibrated using the **AIPS** package, and imaged and self-calibrated using **Miriad**. The work is in progress, calibration in polarisation is done, RM Synthesis is going on. However, the continuum map in Stokes I already looks promising (see Fig. 2)!

- RMS in the image is 0.3 mJy/beam.
- The first contour is at 1 mJy.
- The contours show a "boxy" structure, which is reminiscent of the morphology seen in X-rays and Hα.
- Spectral indices in the galactic disk are close to thermal (Fig. 3). As one moves along the minor axis of the galaxy, away from the disk, the spectral indices become steeper, reaching a value of around -1 at the southern edge.
- Fig. 4 shows the radio continuum spectrum of NGC 1569. For its decomposition into the thermal and nonthermal parts we have used a thermal (free-free) flux density of 100 mJy at 1 GHz, as obtained by Lisenfeld et al. (2004). The blue line superimposed onto the nonthermal flux densities represents the function

$$S_\nu = S_{nth} \cdot \left(\frac{\nu}{\nu_b}\right)^{\alpha_{nth}} \cdot e^{-\left(\frac{\nu}{\nu_b}\right)}$$

where ν_b = 15 GHz is the break frequency beyond which the spectrum drops off exponentially. The low-frequency spectrum is defined by the nonthermal spectral index α_{nth} = -0.4. The spectral break, which had also been found in earlier studies, is evident. This will be subject to scrutiny by 'measuring' this break frequency and hence the particle ages across the galaxy. To this end, we now have maps between 392 MHz and 8 GHz at our disposal.

Further Goals

This observation with WSRT is crucial for bridging the gap between the higher frequencies and future observations with LOFAR. Enumerated below are our goals in brief:

- Determine the size of the synchrotron halos. This is our prime goal, which will enable us to find those relativistic particles that have spread out from the galaxy and cannot be traced anymore at higher frequencies. The emissivity of the synchrotron halo will be compared with that of other outflow tracers, such as X-rays and Hα.
- Measure the spectral index as a function of galacto-centric distance. From this, one can deduce the ages of the relativistic particles.
- Perform a rotation-measure analysis so as to yield information about the magnetic field structure around the dwarf galaxy, an important ingredient for the propagation of relativistic particles. To this end, RM synthesis needs to be performed.

References

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