Seeking large-scale magnetic fields in pure-disk dwarf galaxy NGC 2976

R.T. Drzazga[1], K.T. Chyży[1], D. Elstner[2], J.A. Sellwood[3], G.H. Heald[4], J.S. Gallagher III[5], and W. Jurusik[1]

[1] Obserwatorium Astronomiczne Uniwersytetu Jagiellońskiego, ul. Orla 171, PL30–244 Kraków, Poland
[2] Astrophysical Institute Potsdam, An der Sternwarte 16, D-14482 Potsdam, Germany
[3] Rutgers University, Department of Physics & Astronomy, 136 Frelinghuysen Road, Piscataway, NJ 08854-8019, USA
[4] Netherlands Institute for Radio Astronomy (ASTRON), 7990 AA Dwingeloo, the Netherlands
[5] Department of Astronomy, University of Wisconsin-Madison, 5534 Sterling, 475 North Charter St., Madison WI 53706, USA

Introduction

Otherwise than in massive spirals, the conditions and efficiency of magnetic field generation processes in low-mass galaxies are still not too well understood (see, e.g. Chyży et al. 2011). In search of the large-scale dynamo threshold as well as in order to understand generation and evolution of magnetic fields in such low-mass objects we performed sensitive radio polarimetric observations of a dwarf galaxy NGC 2976 with the VLA at 1.43 GHz.

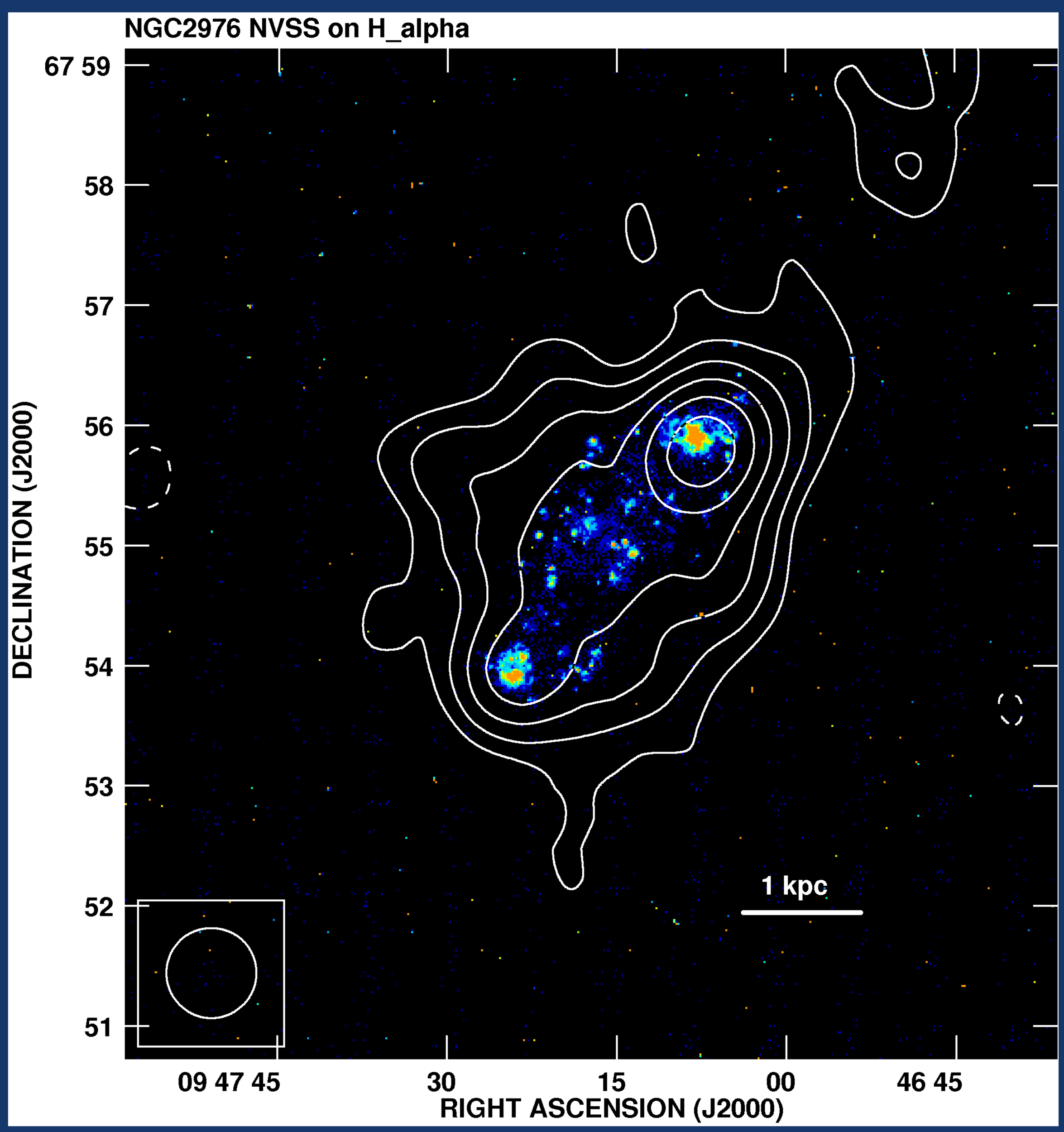

Fig. 1: Total power radio continuum map of NGC 2976 at 1.4 GHz from the NVSS, overlaid upon the Hα image (from the NED database). The contour levels are (-3, 3, 5, 8, 12, 17, 23) × 35 μJy/b.a. The angular resolution is 45" x 45".

NGC 2976 is a dynamically simple, bulgeless, pure-disk object (Simon et al. 2003; Fig. 1,2) of low HI mass (1.5x10^8 M$_\odot$, Stil & Israel 2002a) belonging to the M 81/M 82 galaxy group (Chynoweth et al. 2008). As its linear size is only about 6kpc it seems to be a scaled version of the class of larger pure-disk spirals (e.g. Gallagher & Matthews 2002, Matthews & van Driel 2000). The disk of this galaxy visible in the optical light is possessing well determined, sharp boundaries with regular outer parts. Although NGC 2976 rotates with a velocity of about 70 km/s, which is several times smaller than in typical spirals, it's rotation is still slightly faster than in the case of more massive and larger irregular galaxy NGC 4449 (50 km/s) for which ordered (coherent) magnetic fields were detected (Chyży et al. 2000). Therefore, it is not simple to predict if the large-scale dynamo process operates in NGC 2976.

Distribution of radio emission

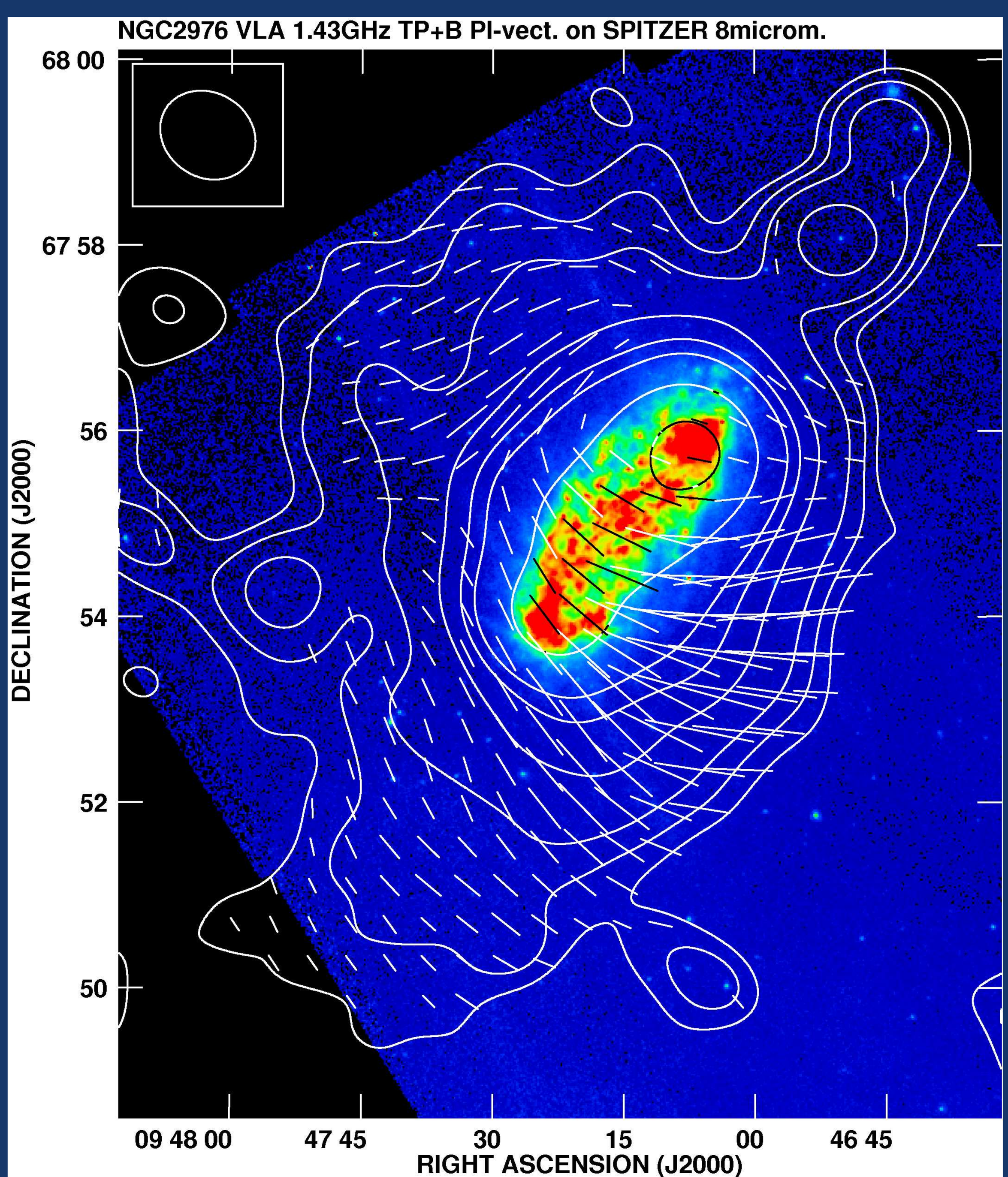

Fig. 2: Total power radio continuum map of NGC 2976 at 1.43 GHz with superimposed B-vectors of polarization intensity, overlaid upon the SPITZER 8 μm image. The contour levels are (-3, 3, 5, 8, 16, 24, 32, 64, 128) × 85 μJy/b.a. (r.m.s. noise level). The polarization vector of 1" corresponds to a polarization intensity of 5 μJy/b.a. The angular resolution is 64" x 55".

Our sensitive VLA observations of NGC 2976 reveal very extended radio emission (Fig. 2). It is asymmetric in respect to the quite symmetric and regular in shape optical disk. The most extensive is the NE appendage. The radio intensity smoothly covers the galactic disk and peaks at the most prominent Hα region where massive stars are formed (Fig. 2).

The distribution of the polarized emission is even more surprising and more asymmetric than that of the total one (Fig. 3). It does not resemble the radio polarized signal typically observed in dwarfs. For these objects the polarized emission usually traces the distribution of Hα regions (cf. Chyży et al. 2011). In case of NGC 2976 we see two lobe-like structures. The southern one is prolonged to SE, like in the total power emission. In the disk region a valley of less polarized signal is observed. It can be caused by the beam depolarization or/and the Faraday depolarization effects. The observed B-vectors (not corrected for Faraday rotation) are parallel to the disk in the northern lobe and perpendicular to it in the southern extension.

Origin of magnetic field

There are only two known mechanisms which can generate regular magnetic fields in galaxies. One of them is a large-scale dynamo producing coherent (unidirectional) fields. The second one is the process of transforming random magnetic fields to regular (random anisotropic) magnetic fields. Such transformation can arise from shearing, stretching or compression of the magnetised plasma, thus from plasma ordered motions.

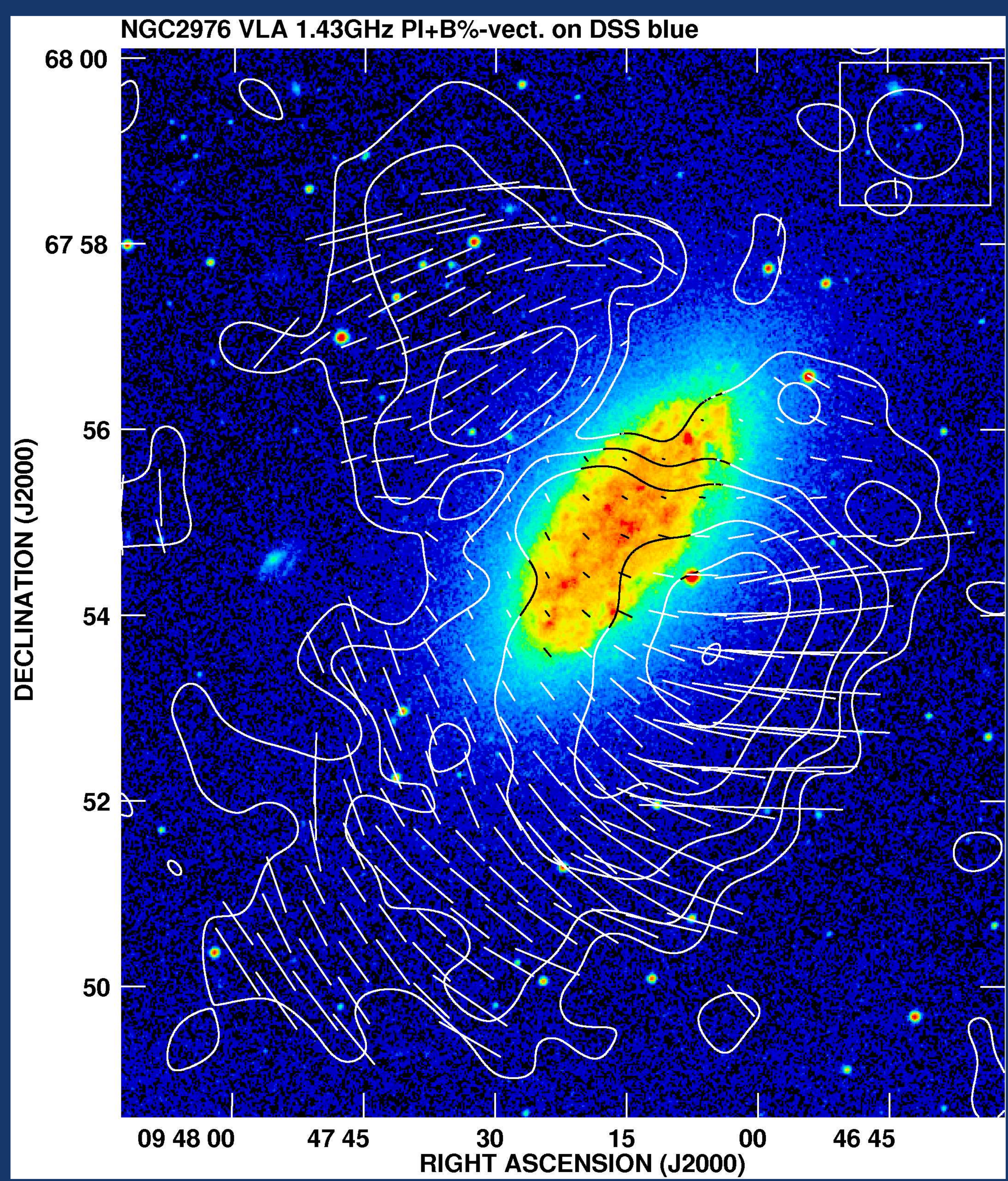

Fig. 3: The contour map of polarized intensity of NGC 2976 at 1.43 GHz with superimposed B-vectors of polarization degree, overlaid upon the DSS blue image. The contour levels are (3, 5, 8, 16, 24, 32) × 15 μJy/b.a. (r.m.s. noise level). The polarization vector of 1" corresponds to a polarization degree of 0.5%. The angular resolution is 64" x 55".

The analysis of a star formation history across NGC 2976 (Williams et al. 2010) indicates that more than about 1 Gyr ago interaction with the core of M81/M82 group could triggered significant gas inflow to the galactic centre (cf. Fig. 4). We expect that during such accretion shearing forces could transform random magnetic fields to the anisotropic ones, which could in turn produce the observed polarized emission within the disk.

Another possibility is a past ram-pressure stripping which could again cause conversion of random to anisotropic magnetic field component and align the field lines with the compression front. The asymmetric distribution of HI gas and associated diffuse total radio emission outside the optical disk (Fig. 5) indicate a close connection of the present radio appearance of NGC 2976 with its past evolution. The stripping could take place in the northern part of the disk (Williams et al. 2010), where B-vectors are actually aligned with the disk edge. Similar phenomena have already been observed in several Virgo cluster spirals (e.g. NGC4501, Vollmer et al. 2008) but not in dwarf objects, yet.

The third possibility to explain the observed structure of regular magnetic field is a large-scale dynamo process. However, dynamo itself cannot be the only process responsible for the topology of magnetic field in NGC 2976. It does not resemble any known configuration of combined azimuthal and vertical magnetic field components recognized e.g. in a sample of SINGS galaxies (Braun et al. 2010). Thus, to reproduce the observed data the dynamo-generated magnetic fields had to be spread out into the galactic halo by galactic winds or by past gravitational interactions.

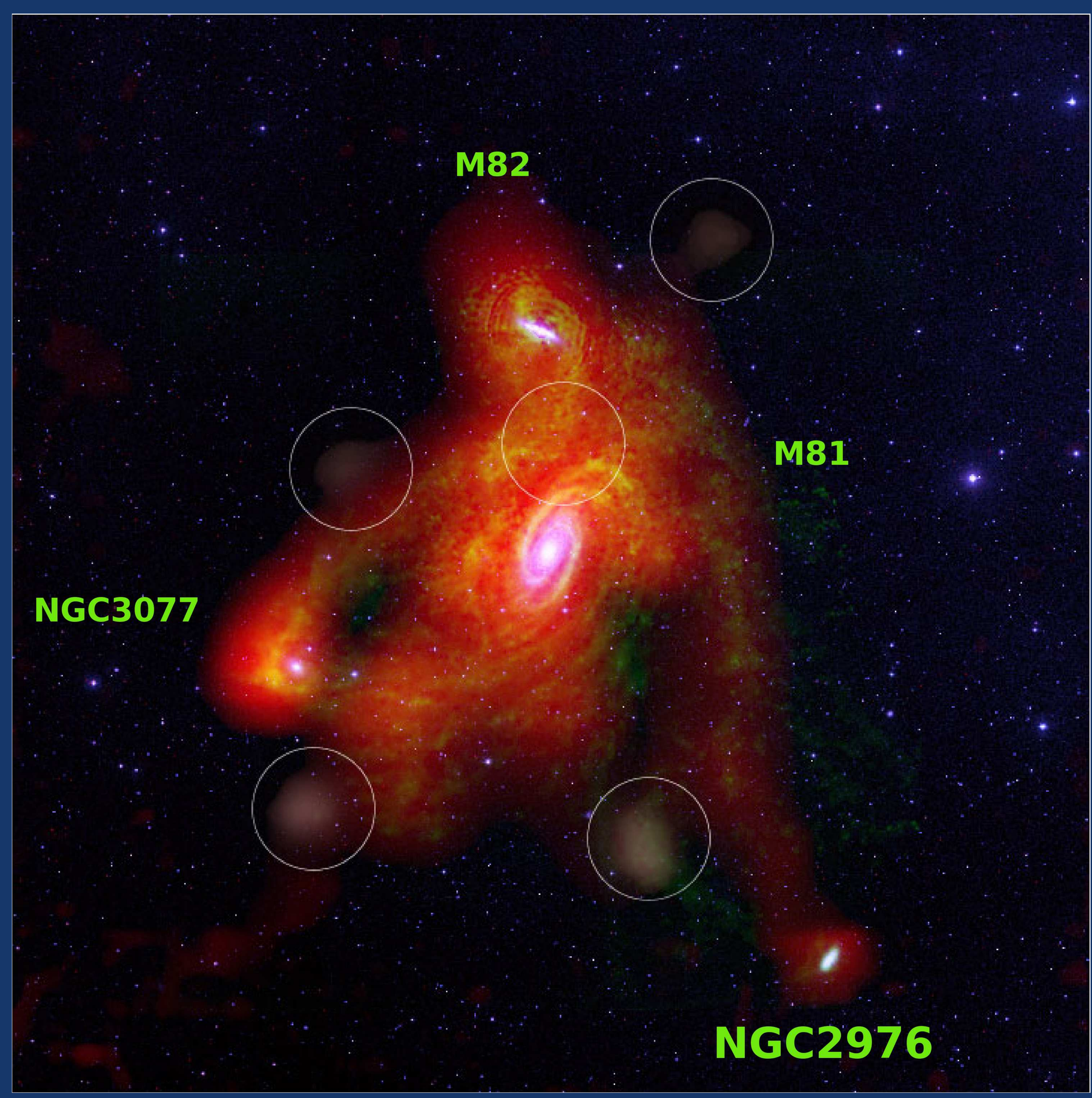

Fig. 4: Distribution of neutral hydrogen in the central part of the M81/M82 galaxy group (Chynoweth et al. 2008). Note, the HI bridge connecting NGC 2976 and the brightest galaxies in this group.

Future studies

The only way to distinguish between the coherent (large-scale dynamo produced) magnetic fields and the anisotropic ones is by studies of the distribution of the Faraday rotation measures (RM). We are currently at the stage of reduction of high frequency (4.85 and 8.35 GHz) data that we obtained with the Effelsberg telescope. These higher frequencies will also enable us to study depolarization effects and to model the properties of the interstellar medium to form the depolarization valley observed in the disk of NGC 2976. To solve the puzzle of the origin of extended magnetic fields in NGC 2976 we plan to confront the obtained RM maps with the results of the RM-Synthesis method applied to the already available WSRT data (Braun et al. 2010). So, stay tuned!

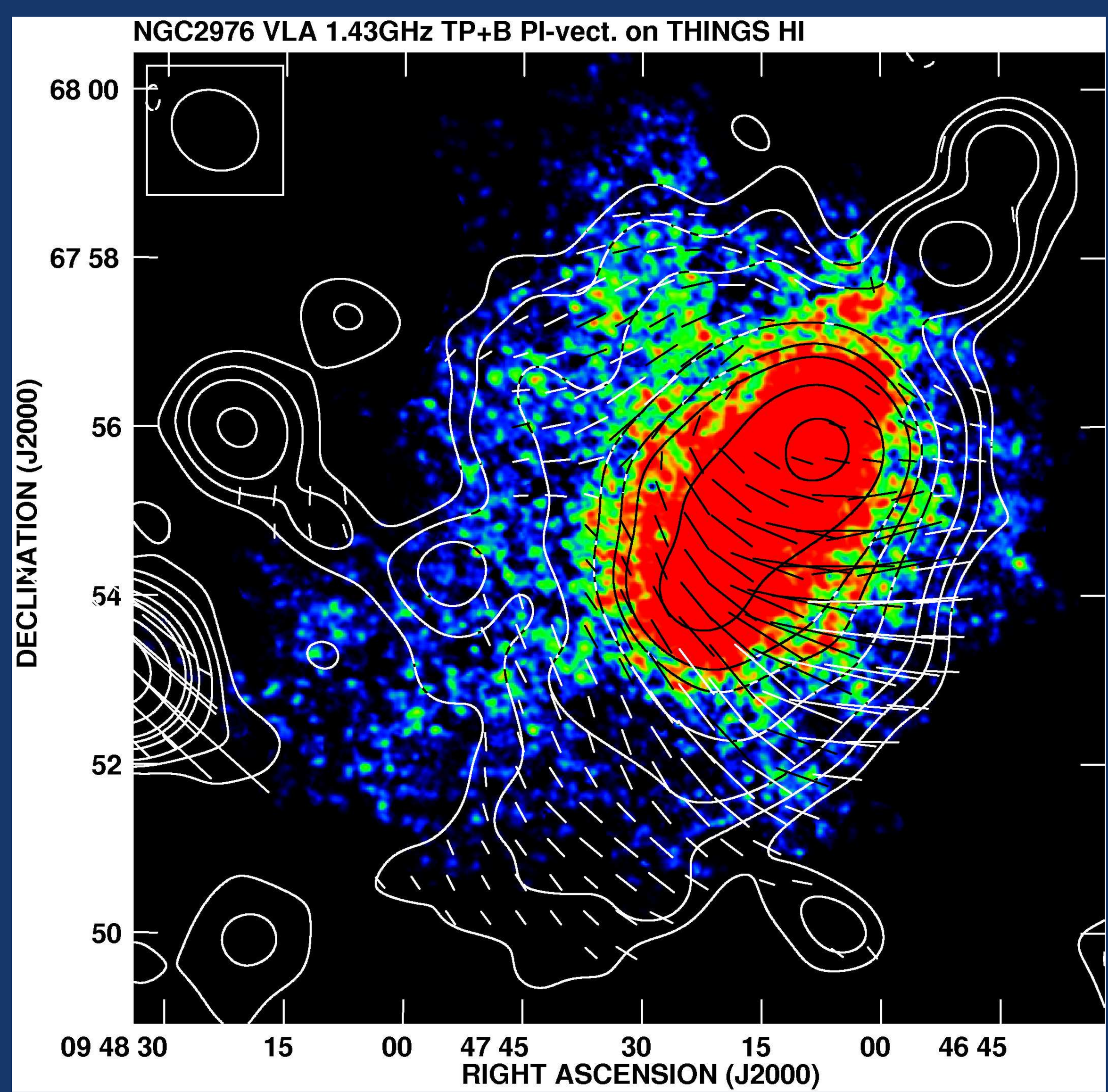

Fig. 5: Total power radio continuum map of NGC 2976 at 1.43 GHz with superimposed B-vectors of polarization intensity, overlaid upon the THINGS HI column density map. The contour levels are (-3, 3, 5, 8, 16, 24, 32, 64, 128) × 85 μJy/b.a. (r.m.s. noise level). The polarization vector of 1" corresponds to a polarization intensity of 5 μJy/b.a. The angular resolution is 64" x 55".

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