# Interactions of radio lobes of NGC4569 with the ICM

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## Cluster environment of NGC 4569

There are a number of environmental effects in clusters that modify spiral galaxies causing their chemical evolution, morphological transformations and strong dynamical evolution (Boselli & Gavazzi 2006). Here we report on our high resolution VLA radio polarimetric observations of the Virgo Cluster spiral NGC 4569. We discuss the influence of the cluster environment on the properties of its radio emission and magnetic fields.

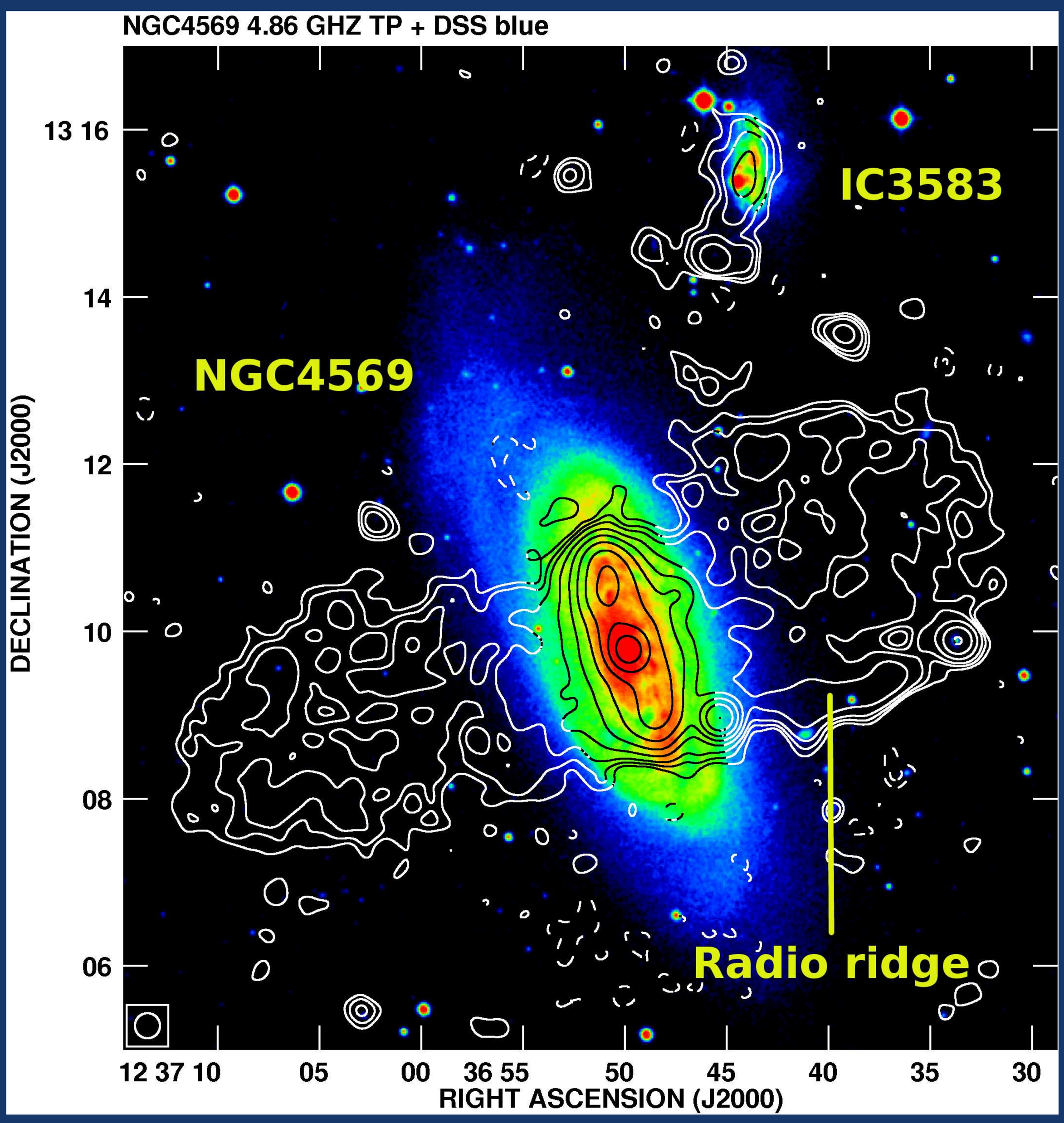


Fig. 1: Total power radio continuum map of NGC 4569 at 4.86 GHz (VLA+Effelsberg) overlaid upon the blue image from the DSS. The contour levels are (-5, -3, 3, 5, 8, 16, 32, 64, 128, 256, 512) × 9 (r.m.s. noise level) $\mu$Jy/b.a. The angular resolution is 18".

NGC 4569 is a bright spiral galaxy (Sb) whose projected angular distance to the Virgo Cluster center (M87) is only 1.7° = 0.5 Mpc. Such close location to the cluster centre might have seriously changed the gas content in the galaxy disk and in its gaseous halo. As the galaxy is highly deficient in HI gas (having only 10% of HI mass of a typical field galaxy of the same morphological type, Giovanelli & Haynes 1983) it probably suffered from strong ISM-ICM interactions in the form of severe gas stripping.

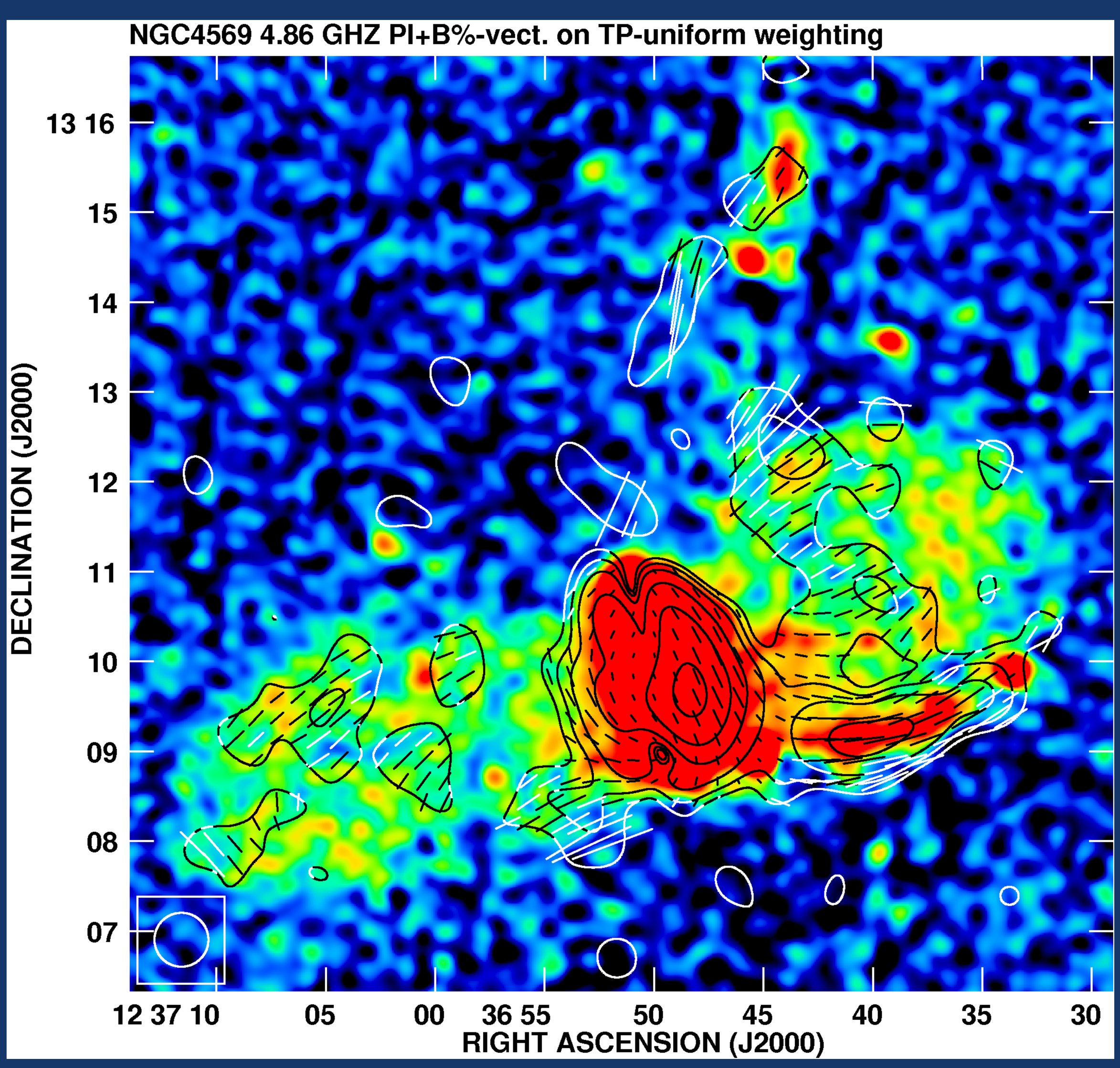


Fig. 2: The contour map of polarized intensity of NGC 4569 at 4.86 GHz with superimposed B-vectors of polarization degree, overlaid upon the total power (uniform weighting). The contour levels are (3, 5, 8, 16, 32, 64, 50, 80) × 15 (r.m.s. noise level) $\mu$Jy/b.a. The polarization vector of 1" corresponds to a polarization degree of 1.7%. The map of distribution of polarized intensity was convolved to 36" to increase sensitivity of diffuse structures.

## The radio lobes

Low resolution radio polarimetric observations with the Effelsberg 100-m telescope at 4.85 GHz and 8.35 GHz (Chyży et al. 2006) revealed in NGC 4569 huge magnetized lobes/bubbles extending up to 24 kpc from the galactic plane. This was the first time that such huge radio continuum lobes were observed in a cluster spiral galaxy.

To study these radio structures in more details we obtained high resolution data with the VLA at 4.86 GHz. The new data confirm our previous low resolution observations but reveal also a slight asymmetry between the two magnetized lobes, the eastern lobe being more elongated and longer by about 20% than the western one (Fig. 1). Such difference may reveal asymmetric engine powering the lobes or more dense cluster environment on the western side of the galaxy. The eastern lobe shows also rather smooth radio emission whereas the western one has a strong radio ridge in its southern envelope.

Differences between the lobes are also visible in the radio polarized emission (Fig. 2). The brightest structure is the polarized ridge in the western lobe associated with a similar structure in the total emission. Its degree of polarization is of about 10% higher than the mean value of the rest of the lobe (about 20%). There is no connection of the ordered magnetic field in this structure to the disc centre which likely excludes an AGN origin of this jet-like looking ridge. Hence, it must have been formed by external interactions likely associated with the cluster environment.

## The disk

Strong radio emission at 4.86 GHz is associated with the disk of NGC 4569 and peaks at the optical centre of the galaxy. However, its main axis is shifted by about $10^o$ from the main direction of optical and also UV emission in the northern envelope of the disk (Figs. 1 and 3). In the central part CO gas has large deviation from circular rotation explained by warping of the stellar disk (Nakanishi 2004).

There is a strong star formation in the galaxy, well visible in many extended H$\alpha$ emitting regions (Fig. 4). The radio extension from the western part of the disk well coincides with one of such regions, a large H$\alpha$ spur of 9 kpc long (Fig. 4, Tschöke et al. 2001). This is likely a recent example of such numerous outflow events which might have delivered ionized and magnetized gas to the galactic halo and to the radio lobes in the past.

The projected magnetic field vectors (B-vectors) are mainly parallel to the disk plane (which is visible at high inclination). In the outer disk regions they give hints for a spiral structure (Fig. 4). A completely distinct magnetic structure shows up in the galactic halo. It traces the H$\alpha$ spur and the shape of the huge radio lobes.

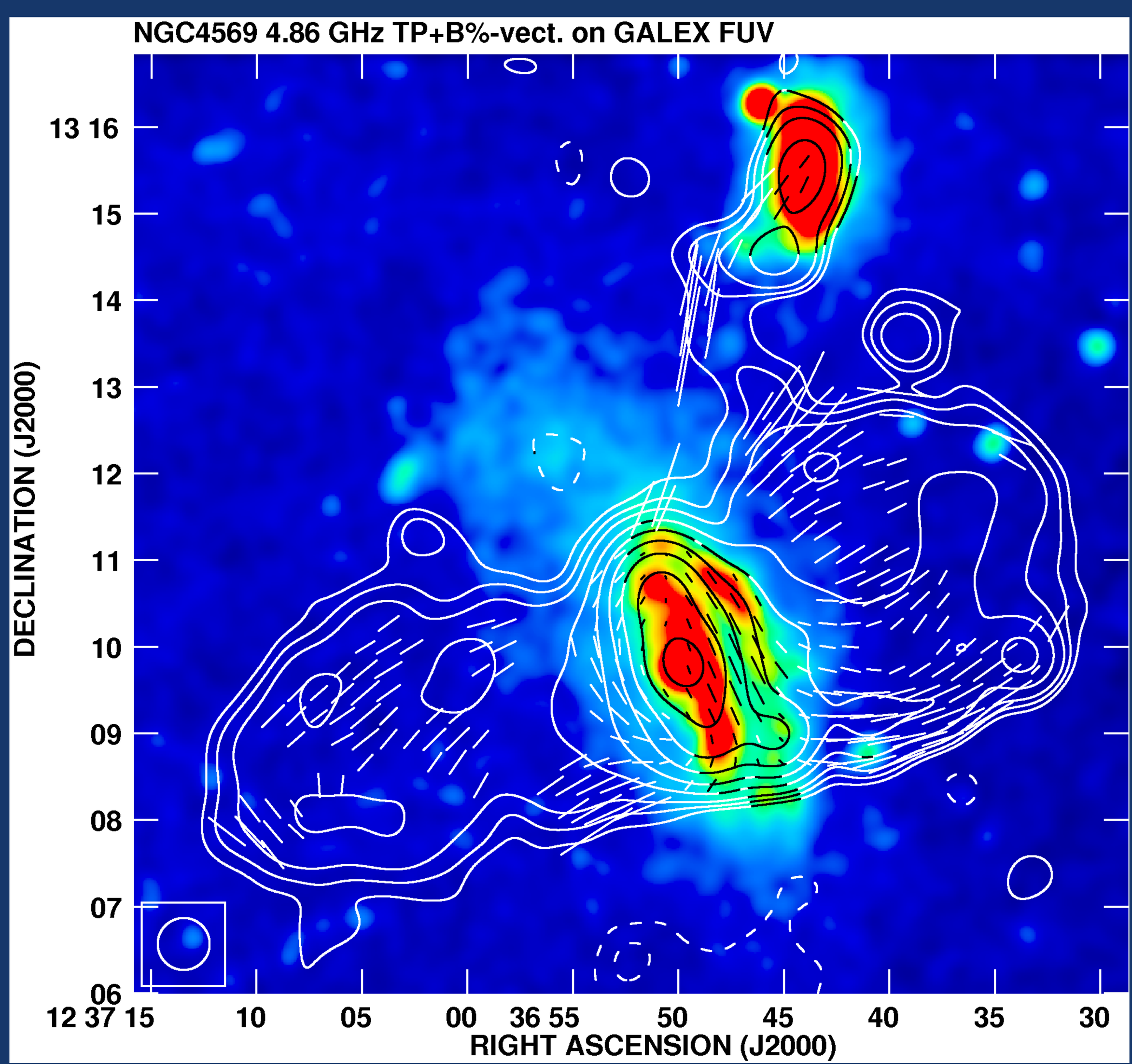


Fig. 3: Total power radio continuum map of NGC 4569 at 4.86 GHz with superimposed B-vectors of polarization degree, overlaid upon the FUV image from the GALEX. The contour levels are (-5, -3, 3, 5, 8, 16, 32, 64, 128, 256, 512) × 18 (r.m.s. noise level) $\mu$Jy/b.a. The polarization vector of 1" corresponds to a polarization degree of 1.3%. The angular resolution is 36".

## The interaction

The HI distribution and velocity field of NGC 4569 suggest that the galaxy is moving with a high speed through the ICM and that it lost its HI gas about 300 Myr ago (Vollmer et al. 2004). The stripped gas that might partly return to the galactic disk could locally compressed magnetic fields and enhanced radio emission. This may explain the observed strong radio ridge in the western radio lobe.

To check this possibility we constructed the Faraday Rotation Measure distribution (RM) taking into account our VLA data at 4.86 GHz and the Effelsberg data at 8.35 GHz (Fig. 5). The RM in the radio ridge is small (about +20 $rad/m^2$) in comparison to the value found in the disk (about +40 $rad/m^2$). Hence, if the ridge does not simply lie in the sky plane the enhancement in polarized intensity is likely caused by anisotropic random fields and indeed could originate from compression of random magnetic field due to external gas.

Because there is no evidence of jet-like structures in NGC 4569 and its LINER nucleus is powered by a star cluster (Keel 1996) the radio lobes are probably caused by a nuclear starburst and superwind-type outflows. This is also supported by estimates of the combined magnetic and cosmic-ray pressure inside the lobes from radio data (Chyży et al. 2006). Such an event requires $10^5$ supernovae explosions and $10^{56}$ erg of total input energy. The current nuclear activity is not sufficient to explain that hence the cause of the radio lobes lies in the past. A stellar population dominated by a large number of A-type supergiants detected in the central region of the galaxy (Keel 1996) might be a smoking gun of such past starburst.

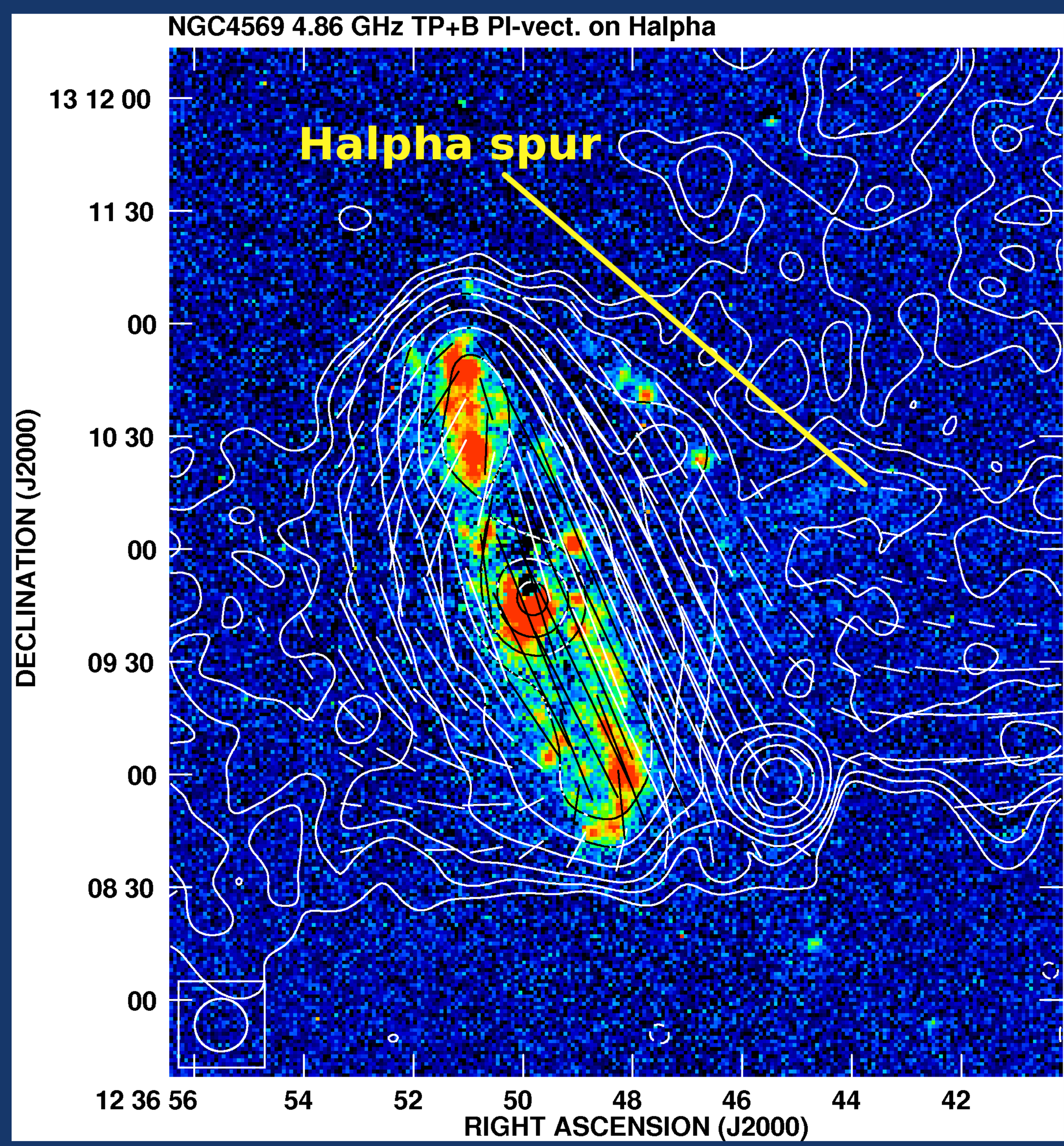


Fig. 4: The contour map of total power emission of disk of NGC 4569 at 4.86 GHz (uniform weighting) with superimposed B-vectors of polarized intensity (36"), overlaid upon the H$\alpha$ image. The contour levels are (3, 5, 8, 16, 32, 64, 128, 256, 512) × 11 (r.m.s. noise level) $\mu$Jy/b.a. The polarization vector of 1" corresponds to a polarized intensity of 12.5 $\mu$Jy/b.a. The map resolution is 14".

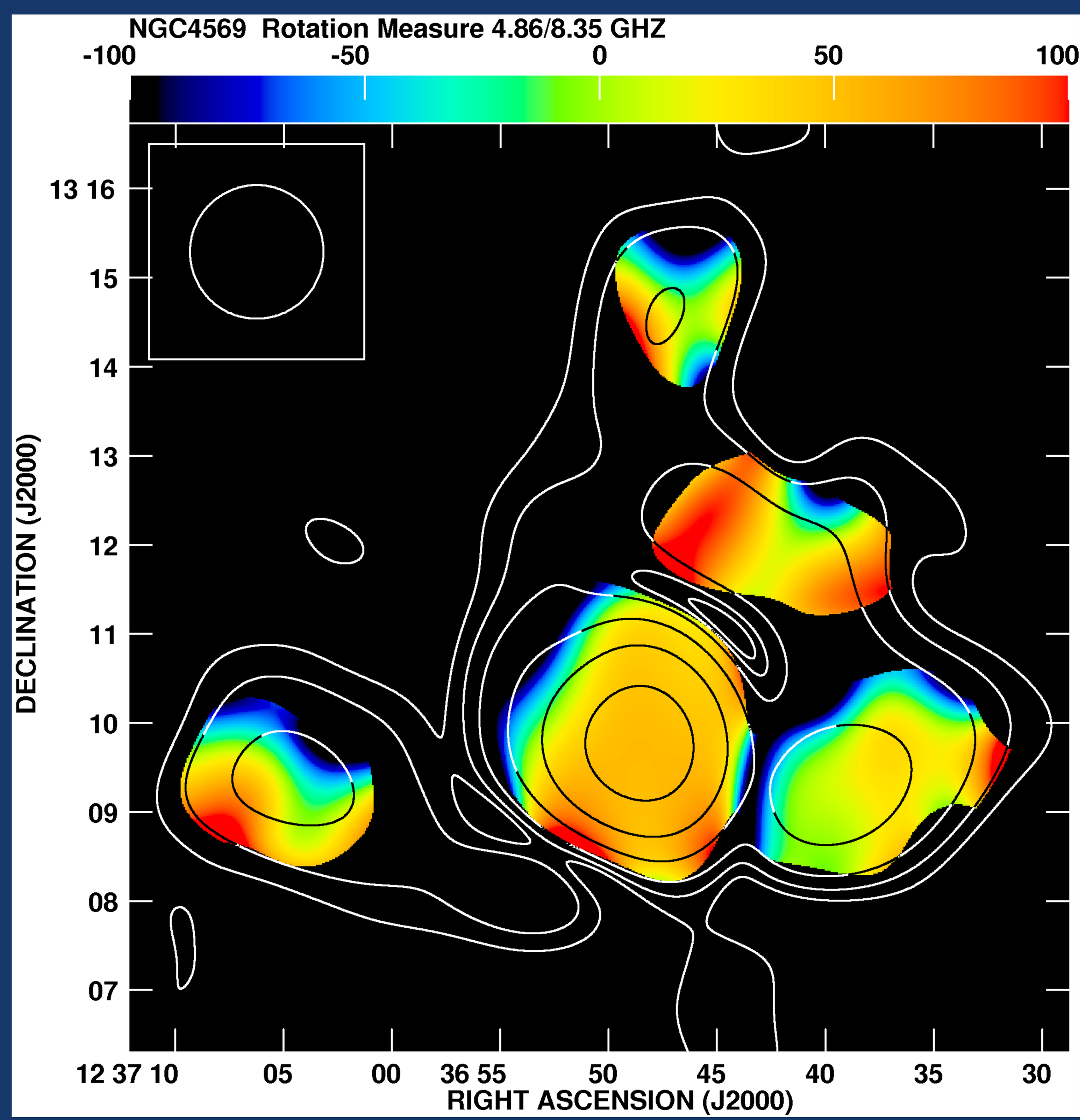


Fig. 5: The distribution of rotation measure in NGC 4569 between 4.86 GHz from our VLA observations and 8.35 GHz from Effelsberg. All the data are convolved to a common beam of 90". The contours delineate the polarized intensity at 4.86 GHz.

In addition to ISM-ICM interactions there are also some hints that NGC 4569 could tidally interact with the dwarf galaxy IC 3583: the radio emission is shifted to the south from the main body of IC 3583 (Figs. 1 and 3); magnetic field B-vectors are aligned with a polarized bridge joining the disk of NGC 4569 and IC 3583 (Fig. 3). Alternatively NGC 4569 could gravitationally interact with the cluster potential (Boselli & Gavazzi 2006). Such interactions could trigger intense star formation activity in the disk of NGC 4569 causing in turn the phenomenon of radio lobes. This scenario requires a combine action of gravitational and ISM-ICM interactions to explain all observed radio features of this unusual spiral.

## References

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