Optical Polarimetry of M83 galaxy : Understanding Dust and Magnetism

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Background

The galactic magnetic fields have two main components: a regular field and a turbulent field. The regular component arises from large-scale dynamo processes. Isotropic fields in the turbulent component are created by processes like supernova explosions, stellar winds, and gas turbulence. Anisotropic turbulent fields result from compression, shear, or ordered flows in the ISM.

While radio observations can very well trace the large-scale ordered magnetic fields, they are unable to capture the small-scale isotropic turbulent fields often present in star-forming regions and galactic outflows.

There are two main mechanisms that cause optical polarization in galaxies: scattering and dichroic absorption. Dichroic absorption can be used to trace the magnetic field structure as they arise from dust grains aligned along magnetic fields, with their long axes oriented perpendicular to the field lines [1]. These grains preferentially absorb the electric field component parallel to their long axes, resulting in net polarization that aligns with the magnetic field direction.

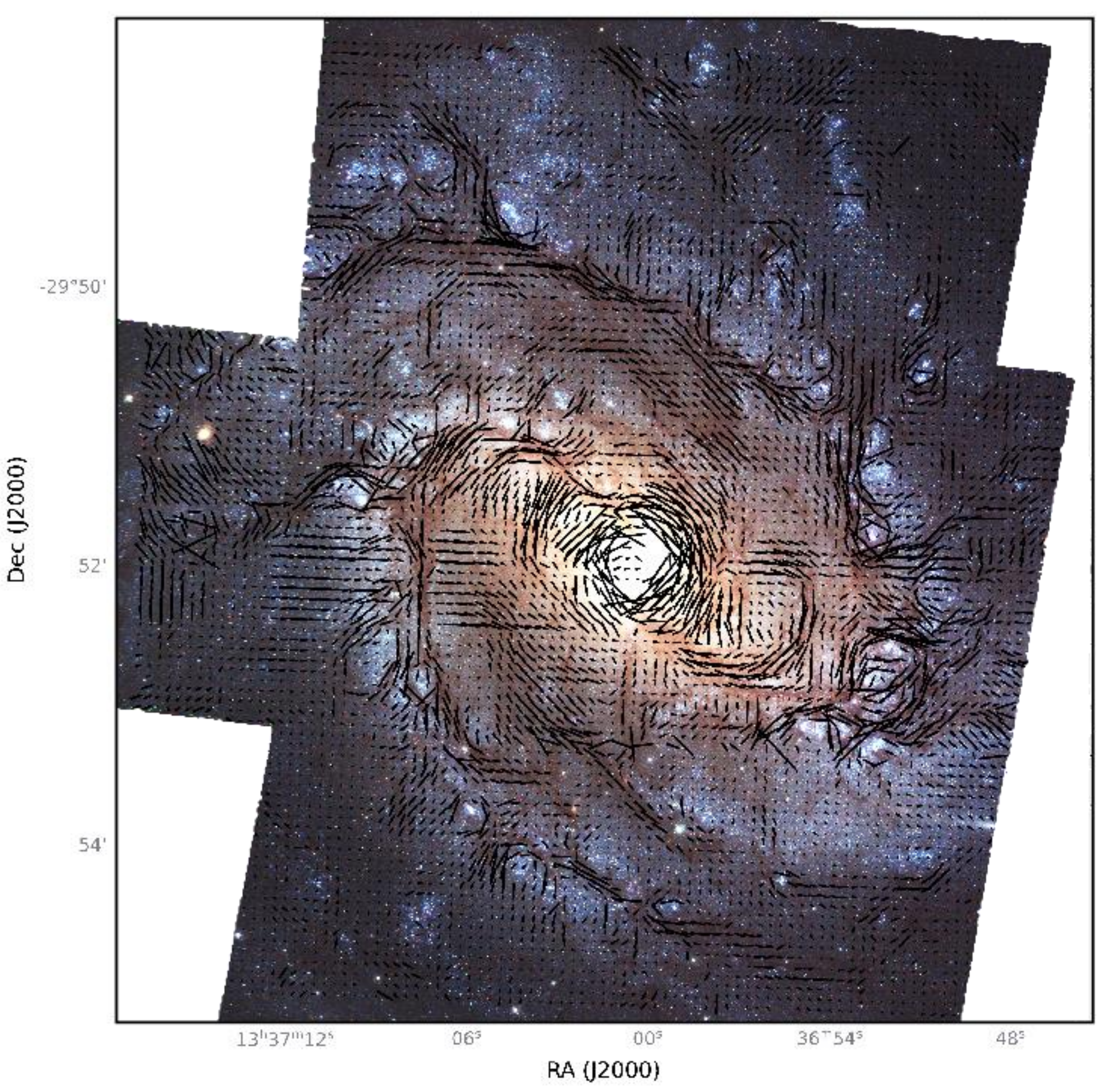
The contribution of scattering is characterized by centrosymmetric polarization pattern, particularly around the galaxy's center and some bright sources

Results

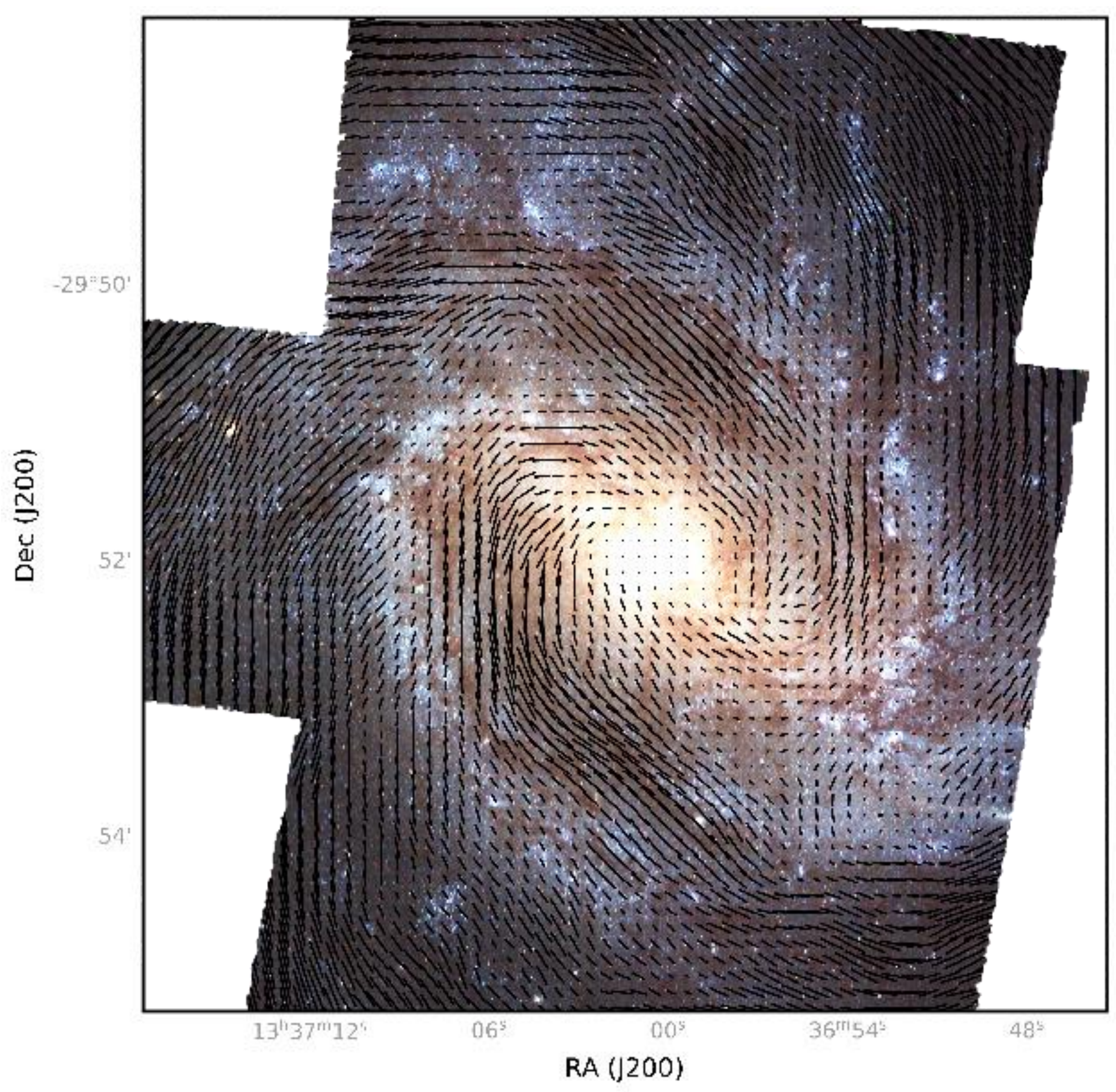
Our results indicate that dichroic extinction is the primary mechanism responsible for optical polarization, as evidenced by the polarization vectors closely following the dust lanes within the galaxy. Figure 1 presents the optical polarization map at 14" resolution, which appears to trace the overall turbulent magnetic fields. Figure 2 shows the radio polarization map at 13" resolution, where the polarization vectors trace the regular large-scale ordered magnetic fields. Figure 3 shows the IR polarization map, at 13" resolution tracing some levels of turbulence.

Since both optical and IR polarization arise from the same dust grain alignment, one would expect similar polarization patterns. However, the discrepancies observed between these maps may be partly attributed to scattering effects in the optical regime, though this remains an open question.

Optical Polarization Map



Radio Polarization Map



IR Polarization Map

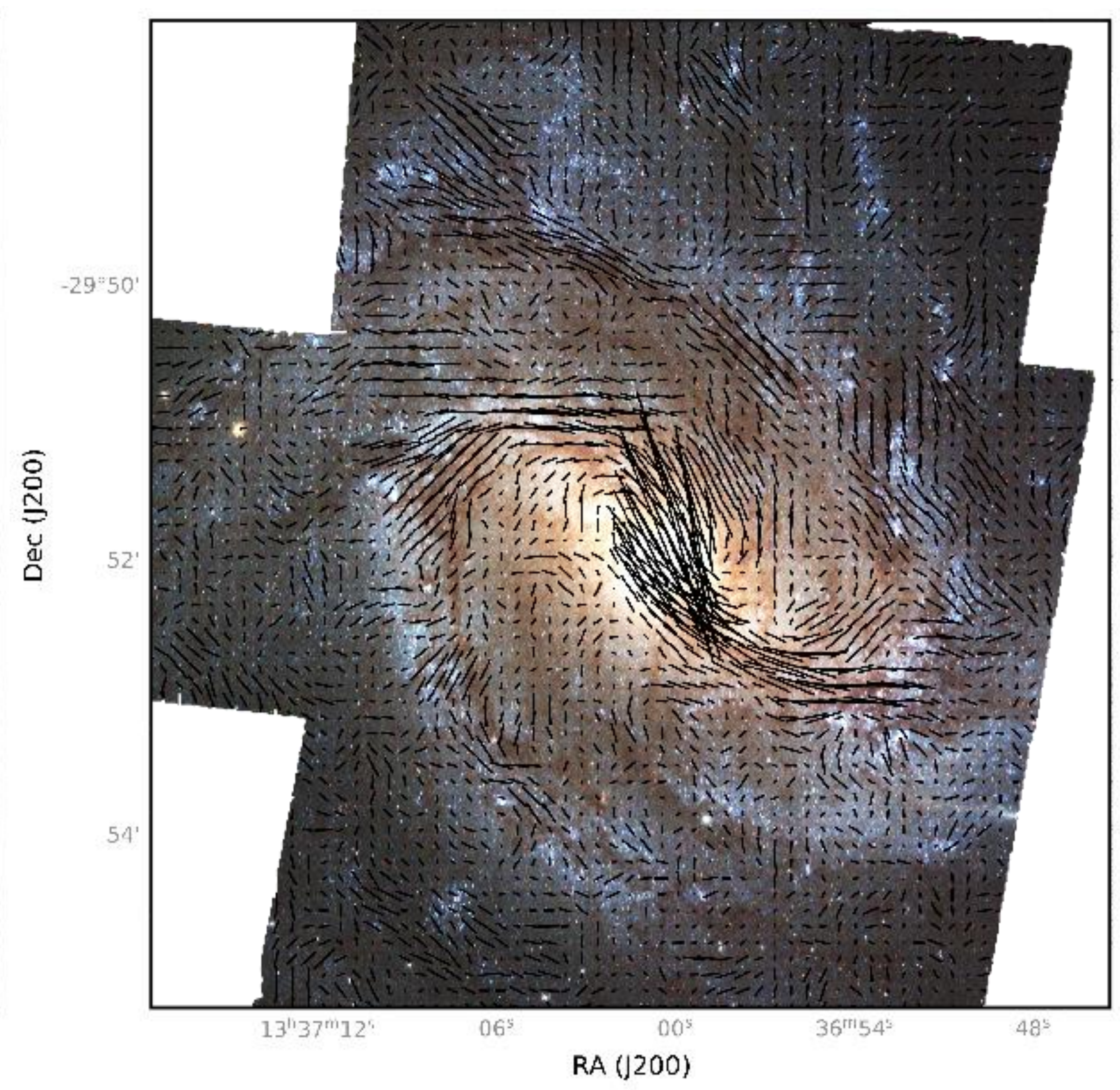
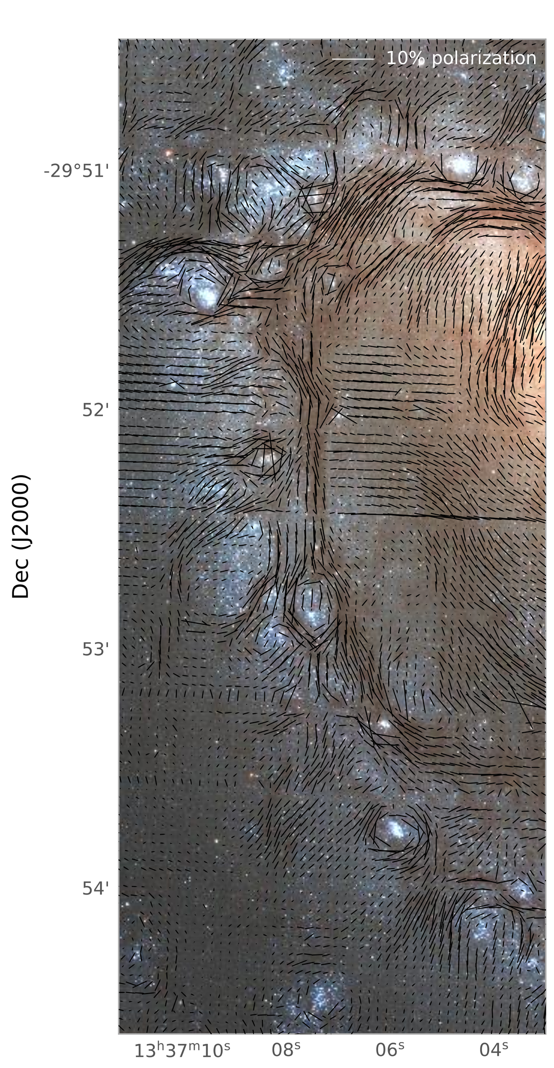
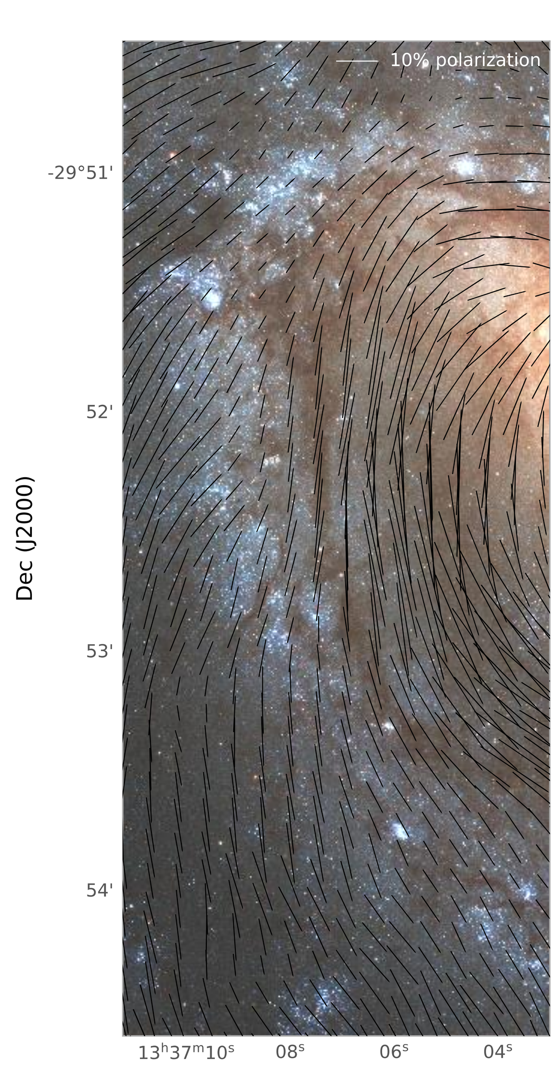
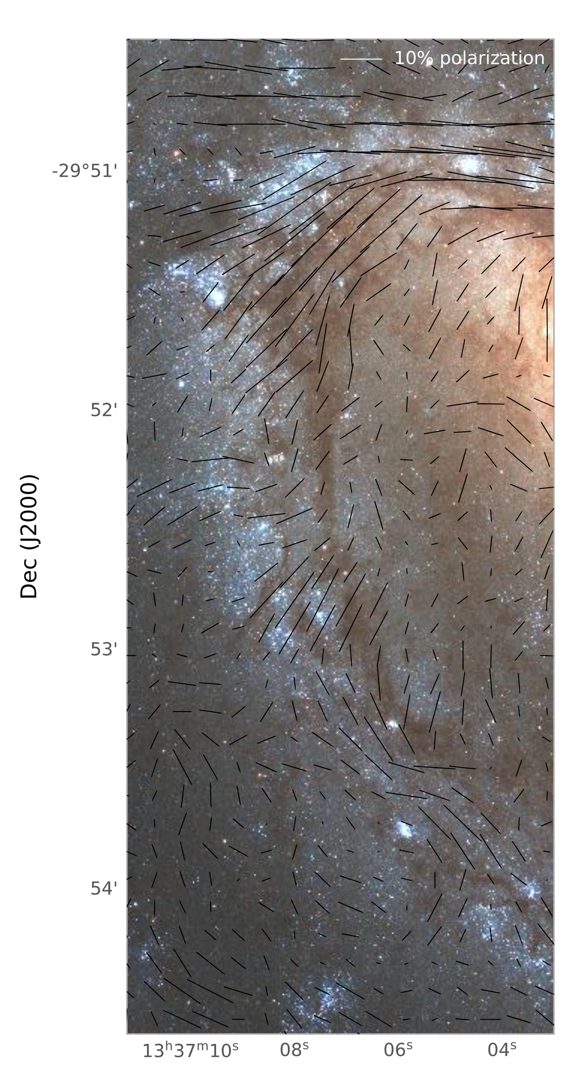


Figure 1 (left) shows the V band optical polarization map [2] at a resolution of 14'' over HST colored image of M83. The black lines show the polarization vectors with length proportional to the polarization degree. The color image was computed using HST F438W (blue), a combination of F555W and F547M (green), and F814W (red) [3]. **Figure 2** (middle) shows the 6 cm radio polarization map [4] at a resolution of 13.6'' over the HST-colored image. The black lines show the polarization vectors with length proportional to the polarization degree). **Figure 3** (right) shows the 154 µm IR polarization map [5] at a resolution of 13.6'' over the HST-colored image. The black lines show the polarization vectors with length proportional to the polarization degree.







In the optical, polarization reveals a magnetic arm offset from the spiral arm, with polarization vectors displaying more chaotic and complex patterns, particularly near dust lanes and regions of star formation. The variation in vector orientations suggests local magnetic field distortions, potentially caused by turbulence or interactions with gas flows.

In contrast, radio polarization shows highly uniform vectors that trace ordered, large-scale magnetic fields. These fields appear less affected by the small-scale turbulence that optical polarization is sensitive to.

Infrared polarization shows an intermediate level of ordering—less chaotic than optical but not as uniform as radio—indicating that it captures some, but not all, of the features detected in the optical.

Figure 4 (left) shows the V-band optical polarization rebinned at a resolution of 7'' in the left spiral arm region. **Figure 5** (middle) shows the 6 cm radio plarization map over the same star-forming region at a resolution of 13.6''. **Figure 6** (right) shows the 154 µm IR polarization map at a resolution of 13.6''. The polarization vectors have length proportional to the polarization degree. The white bar shows 10% polarization.

References

1. Davis and Greenstein, 1951, APJ, 114, 206; 2. Romaniello, et al., 2005, APJ, 629, 250-258; 3. Dopita,et al., 2011, APJ, 710, 964-978; 4. Frick, et al., 2016, A&A, 585, A21; 5. Borlaff, et al., 2023, APJ, 952, 4