A SOFIA-HAWC+ Magnetic Fields Investigation of W51

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Introduction

- This project aims to investigate the **effects of magnetic fields**, using **SOFIA/HAWC+ 53, 89 & 214 μm** dust polarisation data, around the giant molecular cloud complex, **W51**.

- W51 contains 2 massive protocluster regions ("North/IRS2" & "e1/e2") each carrying masses greater than 10^4 M_{sun}, and a broad diffuse shell (called "Main/IRS1"), likely a photon-dominated region, arched in-between them (Ginsburg et al., 2016a, 2017). W51 is located approximately 5.7 kpc from Earth according to Zucker et al. (2018).

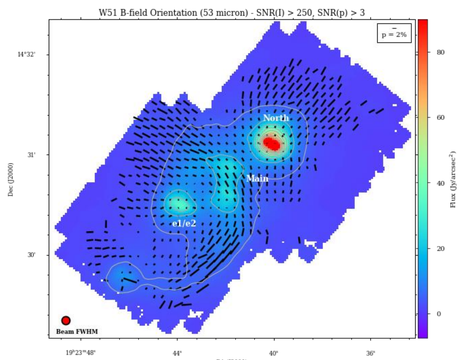

Figure 1 - Magnetic field orientations map of W51 measured by SOFIA/HAWC+ at 53 μm

DAVIS-CHANDRASEKHAR-FERMI METHOD

$$B_{\mathrm{pos}} = Q\sqrt{4\pi\rho}\,\frac{\sigma_v}{\sigma_\theta} \approx 9.3\sqrt{n(\mathrm{H_2})}\,\frac{\Delta V}{\sigma_\theta}$$

Magnetic field strength at the plane-of-sky (B_{POS}) can be estimated using this version of DCF (Crutcher, 2012) by requiring calculations of these key quantities:

1) **$n(H_2)$** - number (volume) density of molecular hydrogen (cm^{-3})
2) **ΔV** – full-width-half-maximum (FWHM) velocity dispersion (km s^{-1})
3) **σ_θ** – polarization angle dispersion (degrees)

Methods

- The general method is based mostly around producing an entire **pixel-by-pixel map of the B-field strength**, similar to Hwang et al. (2021)

- For the **angle dispersion** ‹σ_θ›, we utilised the 'unsharp masking' technique first set out by Pattle et al. (2017), but adapting it to produce maps of the polarisation angle distributions, akin to how Hwang et al. (2021) had done

- For the **velocity dispersion (ΔV)** , we used $C^{18}O$ spectral line data of W51 from Parsons et al. (2012) and utilised the ScousePy (Henshaw et al., 2020) semi-automated decomposition suite to characterise the line data. This allows us to obtain its full-width-half-maximum (FWHM) in km s^{-1}

- For the **volume density $n(H_2)$**, we used *emcee* (Foreman-Mackey et al., 2013) to fit the spectral energy distribution (SED) of 5 different wavelengths from SOFIA/HAWC+ (53, 89, 214 μm) and JCMT-POL-2 (450 & 850 μm). This produces the column density maps in cm^{-2}. Assuming a cylindrical line-of-sight shape, we simply divide the column density by a fixed cloud depth (Ngoc et al., 2023). The cloud depth is estimated based on the auto-correlation function of the integrated polarised flux (Houde et al., 2009)

Preliminary Results

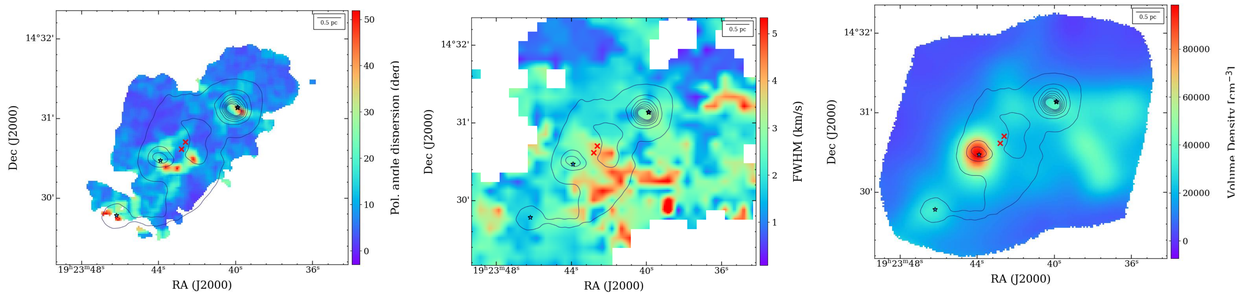

Figure 2 - *(left to right)* Example 53 μm maps of the **angle dispersion ‹σ_θ›** in degrees, **velocity dispersion (ΔV)** in km s^{-1} **& volume density $n(H_2)$** in cm^{-3}

Repeated for all three available SOFIA/HAWC+ bands…

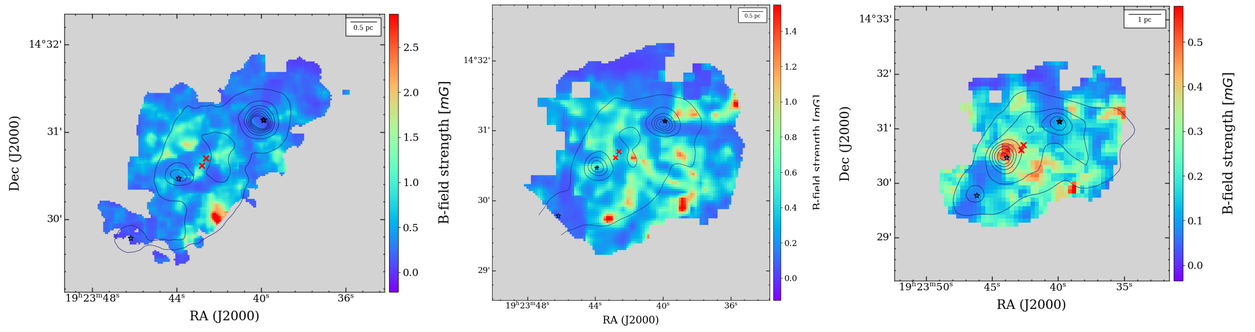

Figure 3 - *(left to right)* Derived B-fields strength maps of W51 using 53, 89 & 214 μm SOFIA/HAWC+ polarisation data

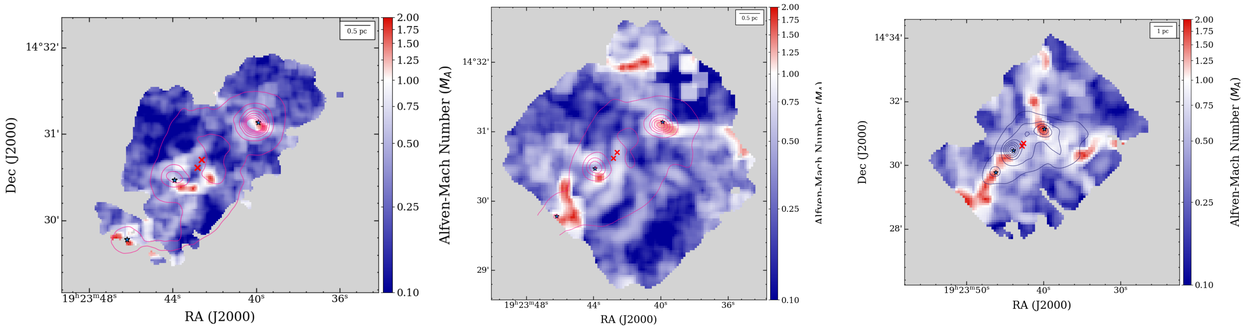

Figure 4: *(left to right)* Alfven-Mach number maps of W51 across 3 bands, calculated from their angle dispersions

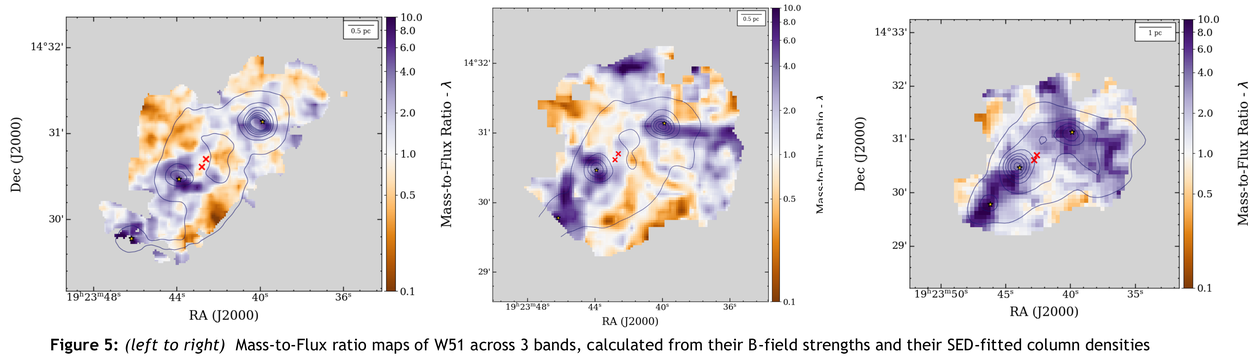

Figure 5: *(left to right)* Mass-to-Flux ratio maps of W51 across 3 bands, calculated from their B-field strengths and their SED-fitted column densities

Discussions

- W51's B-field strength varies approximately from 0.1-2.7 mG (band A); 0.05-1.50 mG (band C) & 0.02-0.6 mG (band E)

- Their mean B-field strengths are ~0.356 mG for band A; ~0.337 mG for band C; ~0.185 mG for band E

- Relatively weak overall B-field strengths when compared to other molecular clouds (Orion A, Oph A, etc..) → could be a distance problem…

- Mass-to-Flux ratio maps and behave as expected, particularly around the collapsing protocluster regions → *mostly* widespread magnetic supercriticality

- Alfven-Mach number maps suggests that W51 is mostly super-Alfvenic, sparing only the Main region.

- The Main region of W51 remains a topic of interest, as its morphology and incredibly dense column density prevents any attempts to detect young stellar objects within its vicinity

- Future works may include further morphological analyses, kinematics derived from spectral decomposition, filament detections, etc… (ideas welcome!)

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