3D MHD Superbubbles
Effects on Interstellar Polarization

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Motivation: Vertical B fields

2.2 microns from Jones. T.J. (1997, Ast J., 114, 1393)
Motivation

Jones, T.J. (1997, Ast J., 114, 1393)
Superbubbles

OB association creates a few tens of type II SN in ~10 Myr

Large energy influx would create hot, low density bubble

“Blowout” as bubble expands into galactic atmosphere

Creates vertical magnetic field
Can Superbubbles cause the observed polarization?

Model a SB event with MHD and then find how the bubble affected Interstellar Polarization.
Wombat MHD

WOMBAT: sWift Objects for Mhd BAseD on Tvd


\[
\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{v}) = 0
\]

\[
\frac{\partial \mathbf{v}}{\partial t} + \mathbf{v} \cdot \nabla \mathbf{v} + \frac{1}{\rho} \nabla p = 0
\]

\[
\frac{\partial p}{\partial t} + \mathbf{v} \cdot \nabla p + \gamma p \nabla \cdot \mathbf{v} = 0
\]

\[
\frac{\partial \mathbf{B}}{\partial t} - \nabla \times (\mathbf{v} \times \mathbf{B}) = \nabla \cdot \mathbf{B} = 0
\]
Simulation Set-Up
Density Profile

Gravity

Assume:

- gravity only in the z direction
- gravity is caused by the exponential distribution of stars

\[ \bar{g} = -G \Sigma_0 \left( 1 - \frac{z}{h} \right) \]

\[ \Sigma_0 = 48 \, Mpc^{-2} \]

\[ h_{stars} = 325 \, pc \]

Pressure and Temperature

\[ \frac{\partial P}{\partial z} = -g \rho \]

Numerically solve for pressure

Atmosphere is static to within less than \(10^{-4} \, c_s\) for resolutions better or at 5pc/voxel

Temperature does not grow unreasonably
Magnetic Field

The field was set by keeping $\beta$, the ratio of the gas pressure to magnetic pressure, constant.

$$\beta = \frac{8\pi P}{B^2}$$

This means that the magnetic field decreases with height above the plane.
Bubble Energy

- Use constant luminosity (Castor, McCray & Weaver 1975)
- Derive luminosity from SN events only, ignore winds (McCray & Karatos 1987)

Where $N \sim 10$

$E_{SN} \sim 10^{51}$ ergs

$T_{OB} \sim 10$ Myr

$L \sim 3.16 \times 10^{37}$ ergs/s
Bubble Evolution
Time = 0 yrs
Time = 5 Myrs
Time = 10 Myrs
Time = 15 Myrs
Polarization Maps
Polarization: Aligned Dust Grains

Integrate along a line of sight through the simulation cube solving the radiative transfer equations for linearly polarized light.

\[ \tau_P = \frac{(1-\eta)}{(1+\eta)} \sin^2(\alpha) \]

\[ I = I_0 \sinh \tau_P + \varepsilon \cos \phi \]

\[ \varepsilon = Q_0 \cos(2\phi) + U_0 \]

\[ I = (I_0 \cosh \tau_P + \varepsilon) \sin \phi \]

\[ Q = (I_0 \cos(2\phi) + Q) \]

\[ U = (I_0 \sin(2\phi) + U) \]

Future work and Conclusions

What is the time scale for this change in polarization? Need to run simulations longer

Add perturbations, could prevent coherent vertical magnetic fields

Vertical fields are created by SB and do produce vertical polarization, however it is not obvious whether the vertical components produced are sufficient to produce observations
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References

Jones. T.J. 1997, AJ., 114, 1393
Constants

AU = 1.5 \times 10^{13} \text{ cm}
1pc = 206265 \text{ AU}
h = 6.62 \times 10^{-27}
e = 4.8 \times 10^{-10}
1\text{erg} = 1.2 \times 10^{12} \text{eV}
a_0 = 5.3 \times 10^{-9} \text{cm}
r_0 = 2.8 \times 10^{-13} \text{cm}
\sigma_{SB} = 5.6 \times 10^{-5}
\Sigma_T = 6.6 \times 10^{-25}
1\text{T} = 10^4 \text{ gauss}
1\text{atm} = 1.013 \times 10^6 \text{ gs}^{-2} \text{cm}^{-1}
Parameters

\[ P_0 = 1.38 \times 10^{-12} \text{ ergs/cm}^3 \]
\[ \rho_0 = 1.67 \times 10^{-24} \text{ g/cm}^3 \]
\[ B_0 = 3 \times 10^{-6} \text{ gauss} \]

Effective Density scale height 105 pc

Mass injected in total = 100 solar masses

Sound speed = 11.73 km/s

Time unit = 5.26 \times 10^{12} s = 166,455 years

\[ g_0 = 6.69 \times 10^{-10} \]