Polarization Signatures of Bow Shocks in Stellar Winds

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Motivation

Stellar wind bow shocks form when a star moving with super sonic speed in the local ISM emits a stellar wind that drives a shock wave into the ISM.

Fig.1:An illustration of bow shock from www.newscientist.com

- They are common circum stellar material configuration (CSM) around massive stars.
- Studying bow shock can probe stellar mass loss, stellar properties, ISM properties it is moving in.
- Bow shocks may provide a link between progenitors and interacting supernovae.

Objective

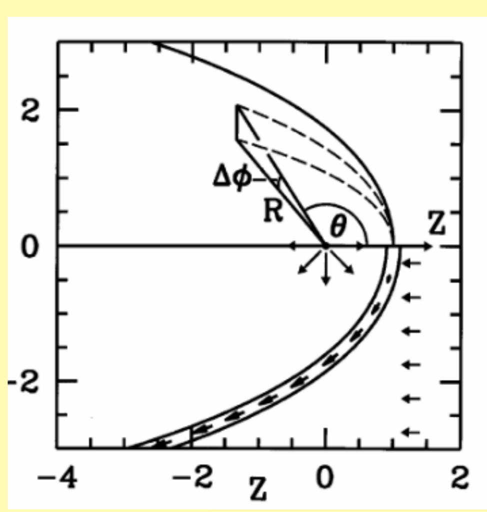
- A bow shock projects an asymmetrical shape onto the sky thus the light from the star become polarized by scattering from electrons and dust in the shock region.
- Polarization signatures can constrain stellar wind speeds, stellar motions, and ISM properties.
- We modeled the polarization produced by scattering in a bow shock with a radiative transfer code. We varied the shock properties to investigate their effects on the resulting polarization signatures.

Method:Analytic formula

For the bow shock properties, we use an analytic model given by Wilkin (1996, ApJ, 459, L31):

$$R(\theta) = R_0 \csc(\theta)\sqrt{(3(1-\theta\cot(\theta)))} \quad (1)$$

$$\sigma = R_0\rho_0 \frac{[2\alpha(1-\cos(\theta)) + \tilde{\varpi}^2]^2}{2\tilde{\varpi}\sqrt{(\theta - \sin(\theta)\cos(\theta))^2 + (\tilde{\varpi}^2 - \sin(\theta)^2)^2}} \quad (2)$$



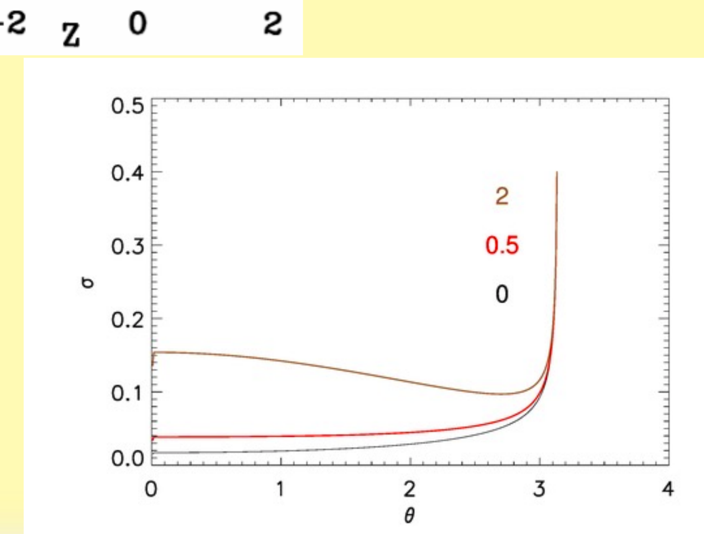


Fig2 (Left):thin shell bow shock model Wilkin et. al, equation (1)
(Bottom):Mass surface density function equation (2)

Method: Simulation

We use Monte Carlo based radiative transfer code ***SLIP*** to do simulations of our model. ***SLIP*** is based on the method of Whitney (2011, BASI, 39, 101). It tracks photons from a central sources as they scatter and become polarized in a user-defined CSM region.

- In this code we can vary different parameters of CSM such as temperature, shape, optical depth,viewing angle.
- We are investigating both eletron and dust scattering. For dust prescription we are using Kim et. al. (1994, ApJ, 422, 164K)
- To take into account direct emission from the dust in the shell, we calculated the shell's projected area as a function of viewing angle and used this function to dilute the polarized flux produced by the scattering model.

Fig.3: (right) Schematic path of photon through *SLIP*.

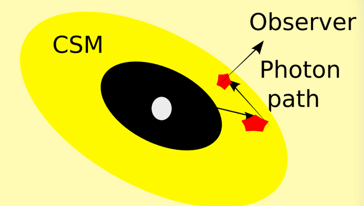
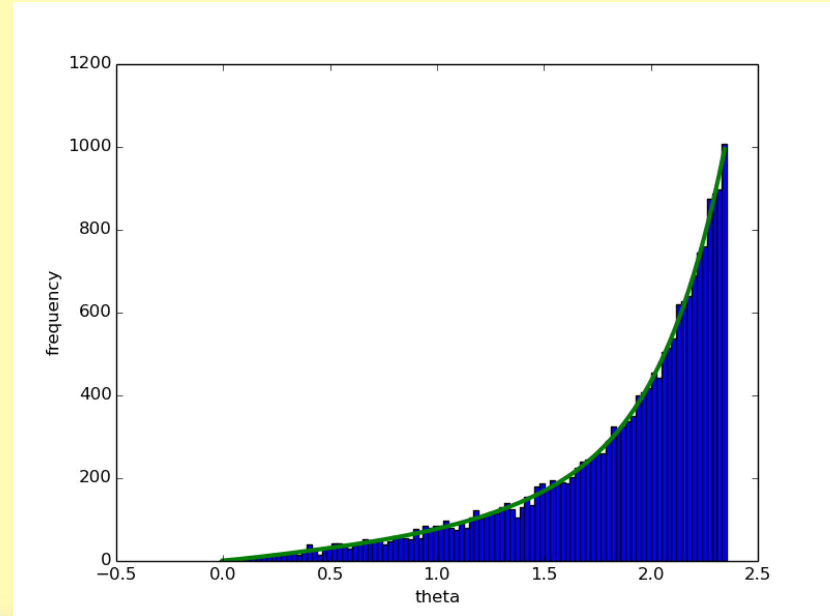
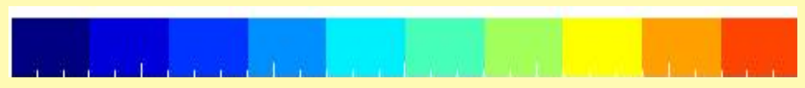


Fig.4: (below) Histogram of photon emission probability and over plot of 7-term power law which define the distribution.



Results

Color bar from 0% to 100%



Viewing Angle | Dust | Electron
θ=0°
θ=45°
θ=90°

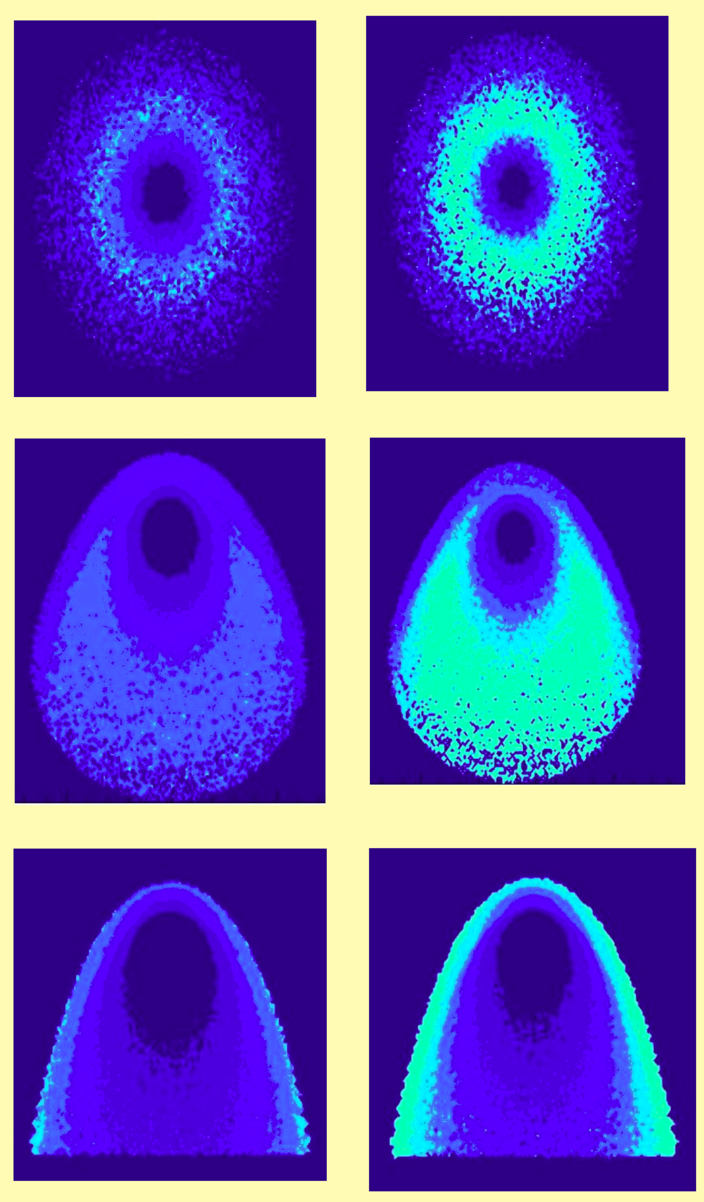
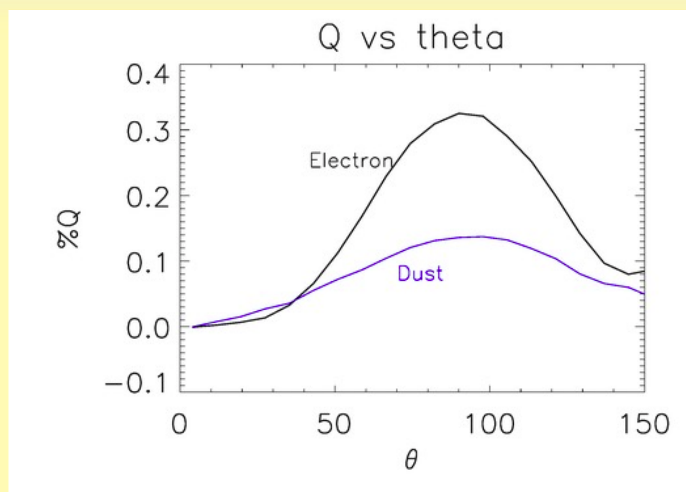
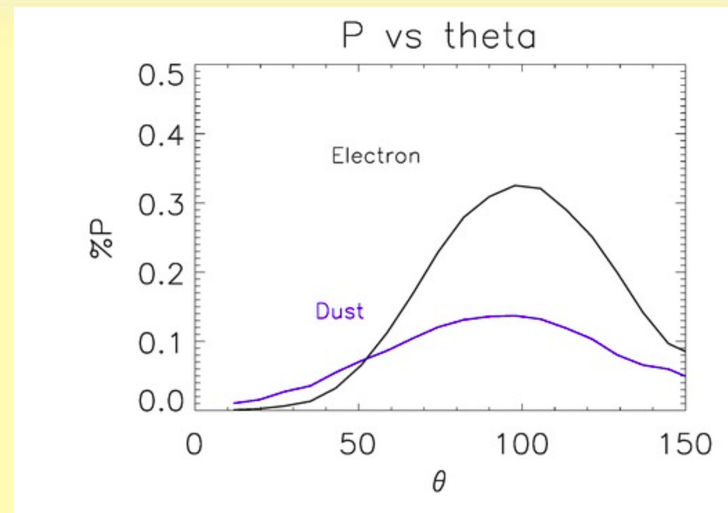


Fig.5(above) Comparison of polarization maps for dust and electron scattering.





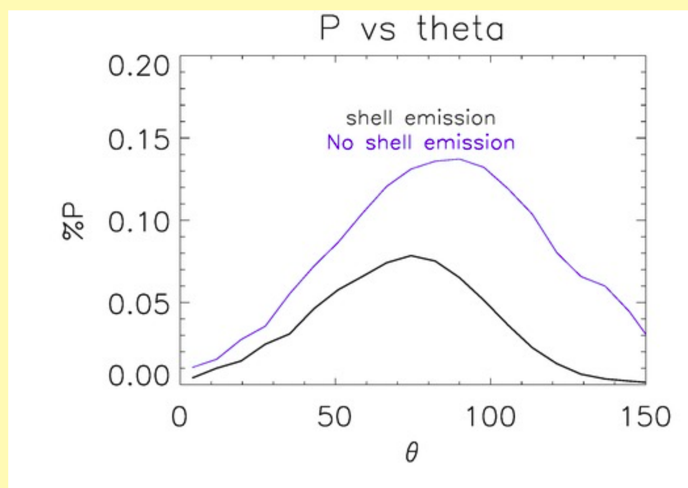


Fig.6 Comparison of %polarization (right above) %Q (left above) for dust and electron scattering at different viewing angle. (Left) Comparison of %P with dust emission and no emission for optically thick case.

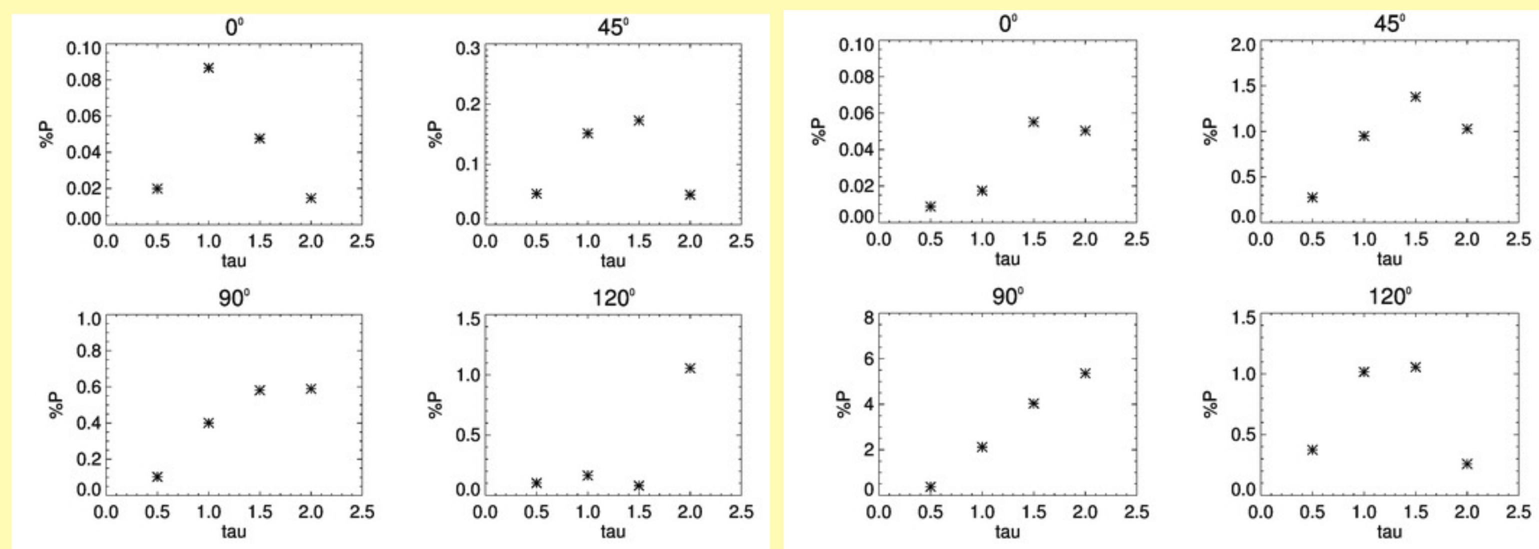


Fig.7 Dependence of polarization on optical depth at different viewing angle. (left) dust (right) electron

Conclusions

- %P and %Q was higher for electron scattering compared to dust scattering at all angles except for (θ)<45^0
- Relation between P and optical depth changes with viewing angle and scattering mechanism.
- In case of optically thick bow shock, the peak of %P shifted to around 65^0 from 100^0 with emission from dust.

Future Work

- For optically thin case, we are calculating emission from dust which is independent of viewing angle. In this case emission depends on mass of dust in bow shock, dust opacity and Planck function.
- Compare results from SLIP with analytical model such as Neilson et. al 2013 .
- Compare the results of SLIP to observational data.
- Add forward and backward shock with different desnities to make it more realistic.

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