MHD Simulations of Line-DriWends from Hot Stars

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Hot-Star Winds

Over the course of their lifetimes, hot, luminous, massive (OB-type) stars lose large amount of mass in nearly continuous outflow called a stellar wind. These winds are driven by scattering of the star’s continuum radiation in a large ensemble of spectral lines (Castor, Abbott & Klein 1975, UAK).

There is extensive evidence for variability and structure on both small and large scales. Our simulations show that magnetic fields may explain some of the large scale variability in wind flow, UV and X-ray emissions from hot stars. There have been some positive detection of magnetic fields in hot stars, e.g. Donati et al. (2001) report a tilted dipole field of $B_{\text{pole}}=300$ G in Beta Cep.

Pneuman and Kopp Model of Solar Corona

Magnetically Confined Wind-Shocks (MCWS)

1 Ori C (O7 V)

1991 Solar Eclipse

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Large ensemble of spectral lines (Castor, Abbott & Klein 1975; CAK)

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First dynamical model of coronal streamers: Pneuman and Kopp (1971) using iterative scheme (left panel). Dynamical MHD reproduction of this model using time explicit magnetohydrodynamic code (ZEUS-3D).

At sunspot minimum, Sun has a global dipole magnetic field of about 1 Gauss. Right panel: solar wind outflow speed at 1 AU as a function of latitude. Magnetic fields can modulate stellar winds.

Relaxation of Wind to a Dipole Field

Global Structure

Inner Wind

Fixed $\eta_1 (=10)$, Different Stars

Conclusion

Magnetic Effects on Solar Coronal Expansion

MHD model for base dipole with $B_{\text{pole}}=1$ G

Our Simulation

Mass Flux and Radial Outflow Velocity

Velocity Modulation

Vsin$i$ and $V_{\text{rot}}$

Radial outflow velocity for the case $\eta = 1$ plotted as a function of latitude:

Cun magnetic fields shape Planetary Nebulae? See Dwarkadas, poster 135.09

Classically, these velocities determine the hardness of X-ray emission.

We find: oblique shocks are very important in X-ray emission as well (see next figure)

Log of density and magnetic fields for three MHD models with same magnetic confinement parameter, $\eta_1$, but for three different stars: standard C Pup, factor-ten lower mass loss rate C Pup, and $B^\circ$ Orion C.

Overall similarity: global configuration of field and flow depends mainly on the combination of stellar, wind, and magnetic properties that define $\eta_1$.

Overall properties of the wind depend on $\eta_1$.

For $\eta_1 > 1$, the wind extends the surface magnetic field into an open, nearly radial configuration.

Slow radial speed within the disk is high speed incoming material fully entrained with the disk (big reduction of the speed of post-shock temperature.

See de Messieres et al. poster 135.12 for more on X-rays.

For the strong magnetic confinement case ($\eta_1 > 10$), log of density superimposed with field lines, estimated shock temperature and X-ray emission above 0.1 keV (see preprint ud-Doula & Owocki 2002 for details).

Why is there a lot of hot gas outside the closed loops?

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