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Magneto hydrodynamic (MHD) modelling of supersonic stellar winds using the PLUTO code

Challenges

Massive stars (those with masses of 10 to 100 times that of the Sun) are extremely luminous and have massive, supersonic winds. These winds can have mass-loss rates of around a billion times that of the Sun and terminal velocities of up to 3000 km per second.

We now know that massive stars can have substantial magnetic fields, with surface magnetic fields that can be greater than 1 Tesla (about that in an MRI machine). The strongest magnetic field in a normal star is around 3.5 Tesla (Babcock's star), though values of 0.1 Tesla are more typical. These magnetic fields will alter the Dynamics of the ionised stellar winds, to form a disk like structure. Because the magnetic field axis and the rotation axis of the star are not necessarily aligned, this results in a very complex wind geometry, with substantial impact on the observable properties of the star and it's wind.

Solution

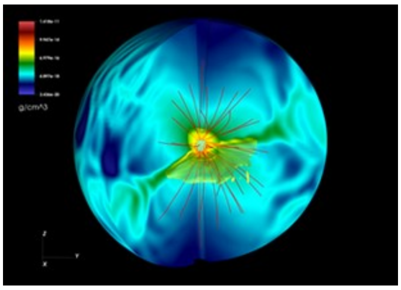
In order to model these "misaligned rotator" model of stellar winds we use the PLUTO Magnetohydrodynamic (MHD) code. We set up a model of the stellar wind, including the radiative driving (the wind is driven by the absorption of the stellar radiation field) and let the wind evolve in the presence of a dipole magnetic field that is misaligned with the rotation axis. An example of the resulting structure is shown, with the inclined disk being due to material flowing along the magnetic field lines and colliding in the magnetic equator region.

Results

Having calculated the expected dynamical structure of the wind, we can then calculate the theoretical expected properties of the star at several different wavelengths. These spectral regions include the sub-mm, optical and X-rays. We are in the process of comparing these with observations taken with X-ray satellites and ground based radio observations.

Caption

The image below shows a slice through the MHD simulation domain of a star with a misaligned magnetic field. The colour map indicates the density structure, showing the disk like structure. The red lines indicate the magnetic field lines. Open field lines indicate lines which do not connect back to the stellar surface. The small light blue sphere at the centre of the image is the stellar surface.



Case study

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Product Used

PLUTO Magnetohydrodynamic (MHD) code

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Funding

STFC
School of Physics & Astronomy

Submitted: 8 November 2016

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