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Radiative MHD simulations of the jets from RW Aurigae

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Abstract. The MHD simulations of stellar jets recently included complex models of radiative emission computation, allowing for better predictions in terms of emission line ratios. Employing also Adaptive Mesh Refinement, the large-scale propagation of jets could be followed. The simulation of multiple shockwaves originating in perturbations close to the jet origin and travelling along the jet beam allows for the construction of synthetic emission maps at various wavelengths, to be directly compared to observations. We apply this procedure for the jets originating from RW Aurigae.

Keywords. atomic processes, MHD, plasmas, radiation mechanisms: thermal, shock waves, stars: winds, outflows

1. Framework

During star formation there is a high probability for the development of jets. Simulating the radiative processes in YSO jets will provide a valuable tool for model discrimination. Employing methods that balance the required accuracy with efficiency for the MHD simulations of jet propagation and emission mechanisms, we were able to construct synthetic emission maps for these objects, to be compared with observations (mainly from the Hubble Space Telescope).

The MHD simulation code we use - PLUTO, is developed and maintained at the Turin University by A. Mignone (http://plutocode.to.astro.it, see Mignone *et al.* 2007). The newly developed cooling module (MINEq) permits a detailed treatment of non-equilibrium cooling losses and is much more accurate than the previously employed models (See Teşileanu *et al.* (2008) for details).

1D simulations were used to explore the parameter space that defines the jet characteristics – mean flow velocity, density, velocity and density perturbation producing traveling shocks in the jet. Emission line ratios are similar in the 1D and 2D simulations, for the same set of parameters (see Table 1).

Table 1. Comparison of emission line ratios for the same parameters, with MINEq cooling.

Simulation	Out	[OI]/[NII]	[SII]/[OI]	Log(OI/NII)	Log(SII/OI)
MINEq 1D	20	6.099	0.954	0.785	-0.021
MINEq 1D	40	11.870	0.899	1.074	-0.046
MINEq 2D	20	12.275	1.055	1.089	0.023
MINEq 2D	40	16.158	1.032	1.208	0.014

2. Numerical Setup

The very high resolution required by the necessity to resolve the post-shock zone where the gradients are steep, as much as the distance scales of the propagation, leaded to the idea of simulating the propagating shock in a reference frame co-moving with the average velocity of the jet material. This was done previously in 1D as a first approximation to simulate highly collimated jets. For the case without magnetic fields the setup was designed and implemented, the tests showing consistency with simulations done in the reference frame of rest. Adaptive Mesh Refinement was also used.

3. 2D Radiative MHD Simulations

The observational data for RW Aurigae jets is from Woitas *et al.* (2002), reconstructed from STIS spectra. Estimating from observations the time employed by the knots to arrive from the base of the jet to their current positions, the relevant output maps from the simulation can be selected. One can apply this procedure for the several knots in the jet, considering their estimated age and various models from the numerical simulations. We have thus begun to generate an array of such dynamical shock models by varying the basic parameters - the jet velocity and density, and the perturbation amplitude.

For the case of best agreement presented in Fig.1, the density was $n_0 = 5 \times 10^4 cm^{-3}$, the jet base velocity $110 km \cdot s^{-1}$ and the amplitude of the initial perturbation in velocity was $40 km \cdot s^{-1}$.

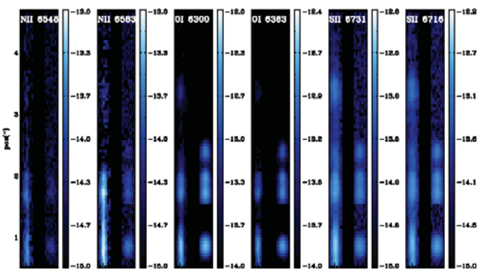

Figure 1. Emission maps in the emission lines of interest. In each frame, on the left is the observed and on the right the synthetic jets. Log scale, in $ergs \cdot s^{-1} \cdot arcsec^{-2} cm^{-2} \AA^{-1}$.

4. Conclusions

The agreement with the observational data was satisfactory, the values in the emission maps being similar in the observed and simulated cases. Several C and IDL routines were developed in order to ease the post-processing of the MHD simulation data and automatically compute average line ratios from the synthetic emission files.

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