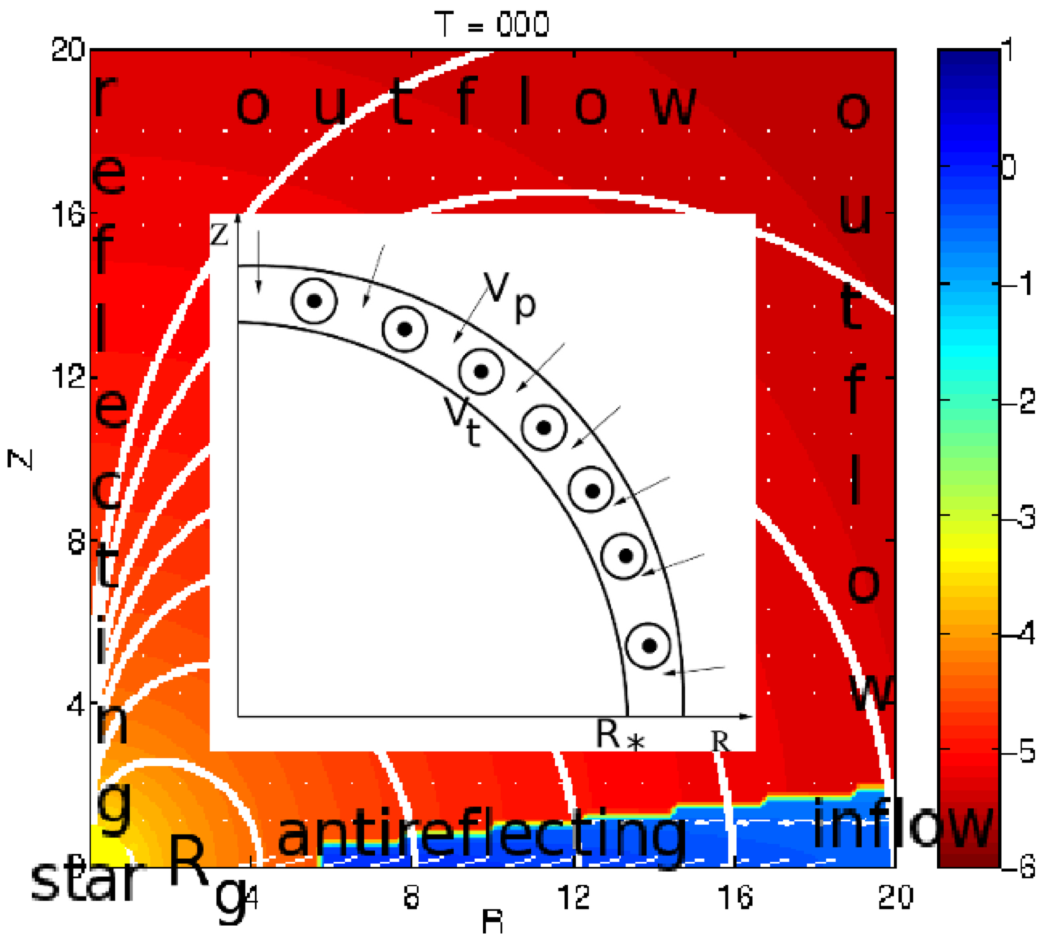
Magnetospheric launching in resistive MHD simulations

Miljenko Čemeljić

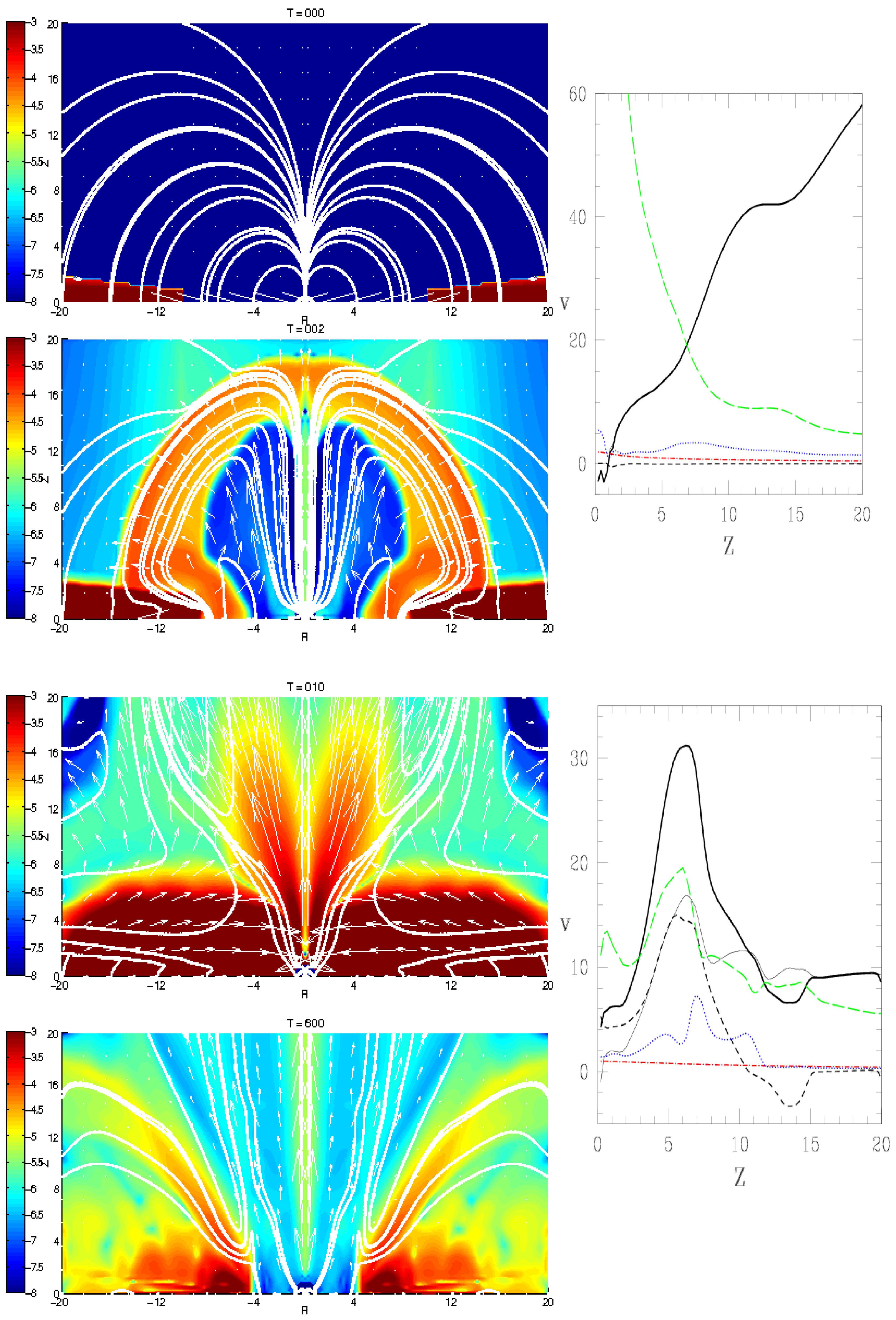
ASIAA/TIARA, Taipei, Taiwan

We perform numerical simulations of outflow launching in the close vicinity of slowly rotating young stellar object. With our resistive Zeus347 code in axisymmetric 2D setup, we find robust stages for magnetospheric interaction, resulting in long lasting quasi-stationary axial and conical outflows.

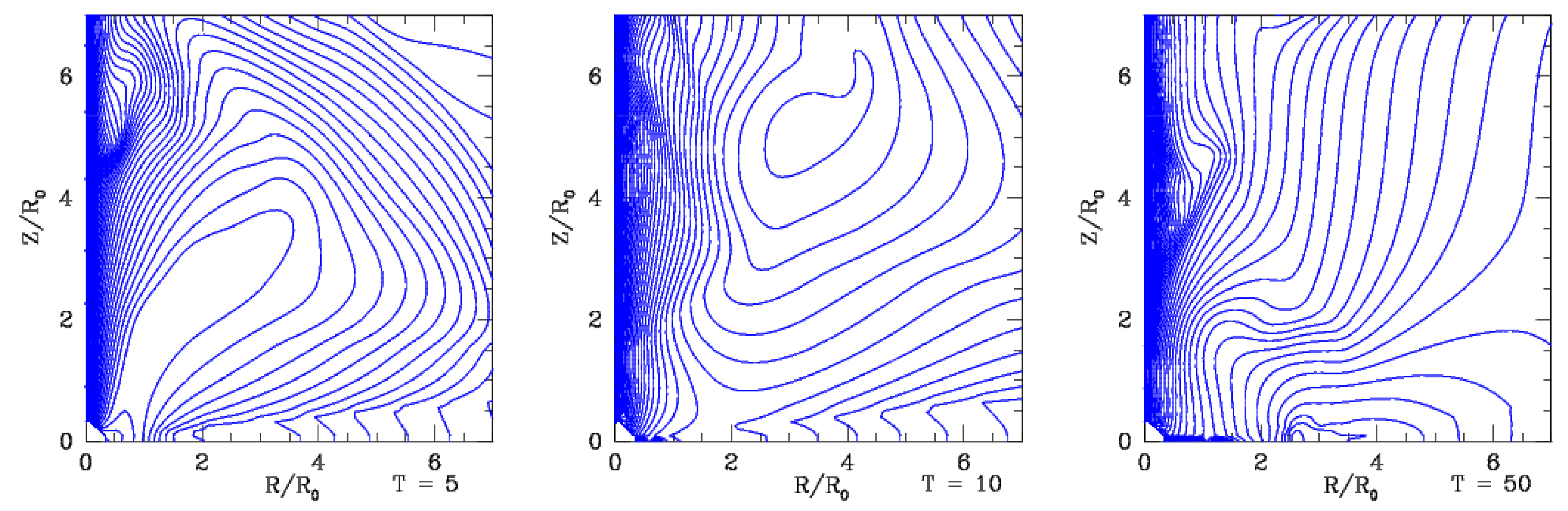
Initial and boundary conditions We set innermost region of a star-disk system, with RxZ=(90x90)grid cells=0.2x0.2 AU. Disk is in a slightly sub-Keplerian rotation, with a rotating, hydrostatic corona and dipole magnetic field centered at the origin. Resistivity in the disk is constant, and in corona it is modeled by density, with η~ρ^(1/3). We solve resistive MHD equations with our ZEUS347 code in the axisymmetry option.



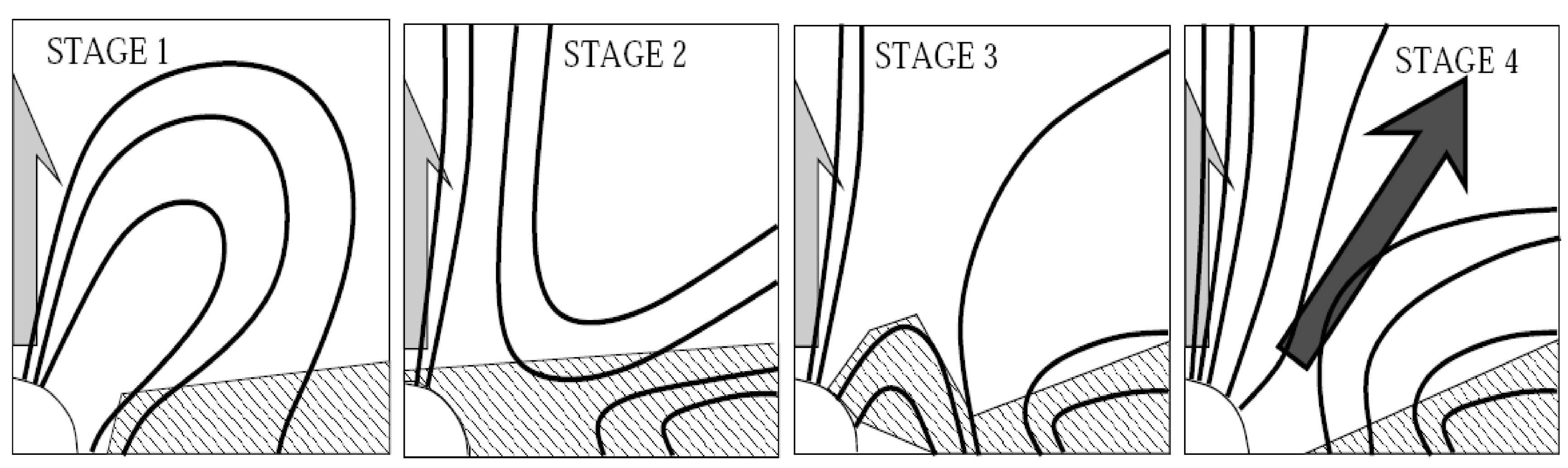
Setup of initial and boundary conditions, with inserted panel showing magnification of stellar surface in sketch drawing. In logarithmic shade grading is shown the density, solid lines show the poloidal magnetic field of a stellar dipole, and vectors depict the velocity. Along the axis of symmetry and the disk equatorial plane, appropriate reflecting conditions are imposed. Outer boundaries are defined as open, except for a disk outer boundary, where inflow into the disk is defined, to mimic accretion from the part of the disk outside the domain. Star is set as a rotating, absorbing boundary condition inside the computational box, enclosing the origin.



Time evolution in simulations with magnetic field of the order of 100 G. In logarithmic color grading is shown the poloidal mass flux, with colorbar shown below the plots. The solid lines show poloidal magnetic field lines, arrows show poloidal velocity vectors. In the final stage conical and axial outflows are ejected from the close vicinity of the star. In the right column panels, shown are velocity components along the axial outflow, at R=1, and along the conical outflow, at R=5, top to bottom panel. In black lines are shown Z, R and toroidal components in thin solid, dotted and short dashed lines, and total velocity in solid thick line, respectively. Dashed green line is Alfven velocity, red dot-dash line is the escape velocity, and dotted blue line shows the sound speed.



Poloidal magnetic field lines are shown for the different timestep in the same simulation.The first three stages are related to the reshaping of the magnetic field, because of reconnection. Resistivity facilitates reconnection, so that in effect result depends on resistivity in the magnetosphere.



All simulations of star-disk interaction in our setup go through four stages: 1) relaxation with pinching of magnetic field inwards, 2) reconnection and opening of the stellar dipole, 3) narrowing of the disk gap with formation of transient funnel flow onto the stellar surface, 4) final stage of equilibrium of magnetic and disk ram pressure, with two outflows, one axial and another conical.

Conclusions: We obtain solutions with two-component outflow from the innermost magnetosphere around the young stellar object. In our simulations we observe four characteristic stages during the outflows launching process. Reconnection plays important role, as it helps in reshaping the magnetic field during the launching of an outflow.