Reconnection and sunsets

Miljenko Čemeljić 席門傑

ASIAA/TIARA

IAA Lunch Box Talk, April 07, 2014

Outline

- History
- Activity
- Work
- Tw&Life
- Sunsets
- *So long*

History

- Mar-Sep 2005, TIARA postdoc in NTHU, Hsinchu
- Back from Greece in Feb 2007, to Dec 2008 TIARA Visiting Scholar, in NTHU, Hsinchu
- Aug 2009-now, “Visiting” Scholar, IAA Taipei

Activity: Selected presentations and posters 1

- Presentation at CompAS meeting, ASIAA, Taipei, Oct. 31, 2013, pdf file
- Poster at PPVI (Protostars & Planets), July 15-20, Heidelberg, Germany
- Presentation at mini Workshop “Bulgeless galaxies and their central engines”, ASIAA, Taipei, March 12, 2013
- Presentation at The Third Cross-Strait Astrophysics Symposium, 6-8 December, 2012, Xiamen University, Xiamen, China
- Poster at The Astronomical Society of the ROC 2012 Annual Meeting (ASROC2012), 25-27 May 2012, National Taiung University, Taitung, Taiwan
- Presentation in IAA Lunch Talk, Taipei, Taiwan, May 21, 2012
- Poster at "ALMA/NAASC 2012 Workshop: Outflows, Winds and Jets" (6th annual workshop), March 3-6, 2012, Charlottesville, USA
- Poster at "Magnetic Fields in the Universe: from Laboratory and Stars to Primordial Structures" (MFU III) conference, August 21-27, 2011, Zakopane, Poland
- Contributed talk at "Spectroimaging Star Formation" Workshop, June 20-24, 2011, ASIAA Taipei, Taiwan
- Presentation at The First SHAO-ASIAA Workshop, Mar 31-Apr 01, 2011, Shanghai, China
- Invited ISAPS seminar, March 24, 2011, NCKU, Tainan, Taiwan
- Presentation at the Star Formation group meeting, IAA, NTU Taipei, Taiwan, Jan 11, 2011
- Contributed Talk in The Fourth East Asian Numerical Astrophysics Meeting (EANAM 2010), November 2-5, 2010, Taipei, Taiwan
- Poster for IAU Symposium 271: Astrophysical dynamics – from stars to galaxies, Jun 21-25, Nice, France

Selected presentations and posters 2

- Contributed Talk in The Astronomical Society of the ROC 2010 Annual meeting(ASROC2010), 28-30 May 2010, IAA, Taipei, Taiwan, 2010
- Presentation in the 1st Crazy Lunch Talk, IAA, Taipei, Taiwan, March 15th, 2010
- Presentation in CFD-MHD Journal Club, IAA, Taipei, Taiwan, January 5th, 2010
- Presentation in IAA Lunchbox Talk, IAA, Taipei, Taiwan, November 23th, 2009
- Presentation in CFD-MHD Seminar, IAA, Taipei, Taiwan, November 10th, 2009
- Presentation in CFD-MHD Journal Club, IAA, Taipei, Taiwan, October 27th, 2009
- Presentation in Final Jetset Meeting, Jena, Germany, 12th January 2009
- Presentation in Astro-Seminar in University of Split, Croatia, 21 December, 2008
- Presentation at The third East-Asia Numerical Astrophysics Meeting (EANAM2008), Nanjing, China, 10-13 November, 2008
- Contributed Talk at the conference "Protostellar Jets in Context", 7-11 July, 2008, Rhodes Island, Greece
- Poster at the conference "Protostellar Jets in Context", 7-11 July, 2008, Rhodes Island, Greece
- Presentation at the CAST2008 meeting, Hualien, Taiwan, June 01, 2008
- Astronomy Colloquium talk in National Central University, Jhongli, Taiwan, Nov 2, 2007
- Contributed talk at the East Asian Meeting of Astronomers 7, Fukuoka, Japan, Oct 19, 2007
- Presentation at the TIARA Early Solar System Mixing workshop, TIARA, Hsinchu, Taiwan, Aug 2007
- Contributed talk at the JETSET 4th School, Ponta Delgada, Azores, Portugal, Jul 2007
- Presentation at CAST96 meeting, Tainan, Taiwan, Jun 3rd, 2007
- Poster at the PSROC2007 meeting, NCU Jhongli, Taiwan, Jan 2007

Work 1: Star-disk simulations; micro-ejections

- Resistive MHD star-disk numerical simulations with Zeus347

The Astrophysical Journal, 768:5 (20pp), 2013 May 1
doi:10.1088/0004-637X/768/1/5

MAGNETOSPHERIC ACCRETION AND EJECTION OF MATTER IN RESISTIVE MAGNETOHYDRODYNAMIC SIMULATIONS

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ABSTRACT

The ejection of matter in the close vicinity of a young stellar object is investigated, treating the accretion disk as a gravitationally bound reservoir of matter. By solving the resistive MHD equations in two-dimensional axisymmetry using our version of the Zeus-3D code with newly implemented resistivity, we study the effect of magnetic diffusivity in the magnetospheric accretion–ejection mechanism. Physical resistivity was included in the whole computational domain so that reconnection is enabled by the physical as well as the numerical resistivity. We show, for the first time, that quasi-stationary fast ejecta of matter, which we call *micro-ejections*, of small mass and angular momentum fluxes, can be launched from a purely resistive magnetosphere. They are produced by a combination of pressure gradient and magnetic forces, in the presence of ongoing magnetic reconnection along the boundary layer between the star and the disk, where a current sheet is formed. The mass flux of micro-ejection increases with increasing magnetic field strength and stellar rotation rate, and is not dependent on the disk to corona density ratio and amount of resistivity.

Work 1

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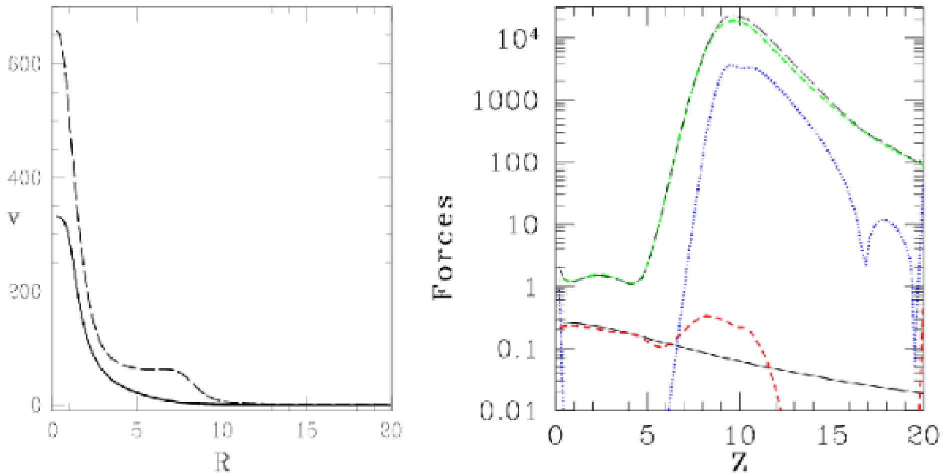
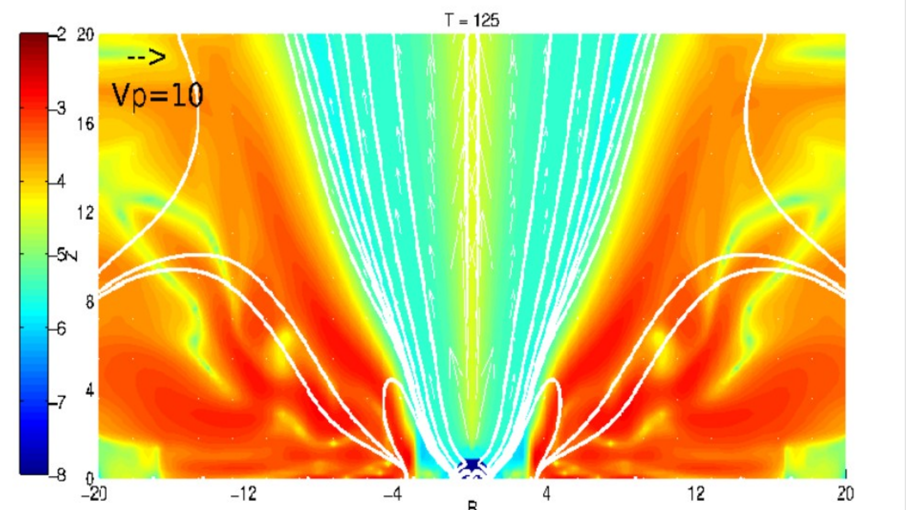


In the left panel is shown velocity in the above simulation, in units of Keplerian velocity at R=2.8 stellar radii, along the outer Z-boundary. Dashed line depicts magnetic field of B=200 G, and in solid line is the velocity with a weaker field of B=20 G. In the right panel are shown forces in code units, in a logarithmic scale, along a slice parallel to the axis of symmetry, at R=5. In blue dotted line is shown the magnetic force, and in solid, green dot-dashed, red short-dashed and black long-dashed lines are shown absolute value of the gravitational force, pressure gradient, centrifugal and total force, respectively. Ejection along the axis is artificial, produced by the steep gradient in magnetic pressure nearby the axis. At larger radial distance realistic, physical ejections occur, and they are mainly launched by pressure gradient and magnetic forces.



Mass flux is depicted in units of mass accretion rate at R=2.8 stellar radii, in logarithmic color grading, in simulation with stellar magnetic field of 200 G. The white solid line shows the poloidal magnetic field, and vectors represent velocity.

Work 2: Magnetic reconnection

Magnetic reconnection in a comparison of topology and helicities in two and three dimensional resistive MHD simulations

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(Dated: 17 March 2014)

Through a direct comparison between numerical simulations in two and three dimensions, we investigate topological effects in reconnection. A simple estimate on increase in reconnection rate in three dimensions by a factor of $\sqrt{2}$, when compared with a two-dimensional case, is confirmed in our simulations. We also show that both the reconnection rate and the fraction of magnetic energy in the simulations depend linearly on the height of the reconnection region. The degree of structural complexity of a magnetic field and the underlying flow is measured by current helicity and cross-helicity. We compare results in simulations with different computational box heights.

Work 2

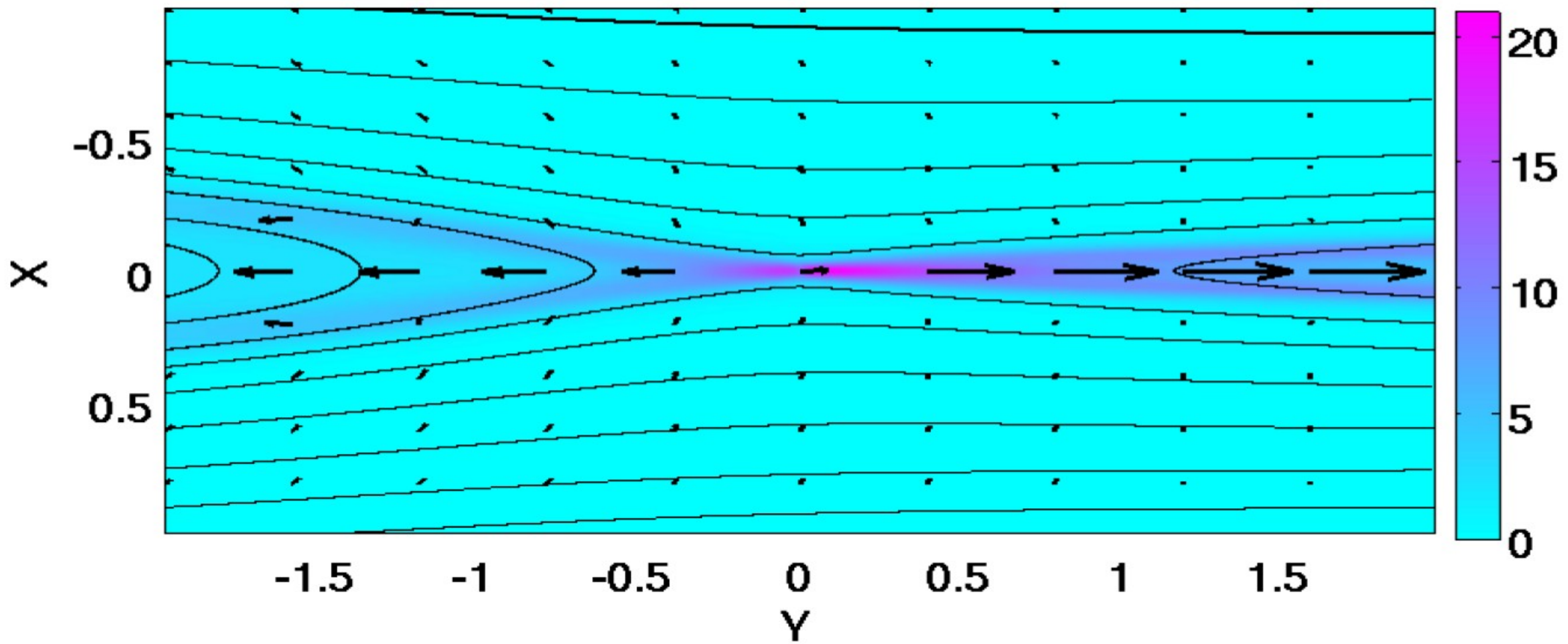

FIG. 2. Reconnection in two dimensions at T=30 in code units, with current density shown in color grading, magnetic field contour lines in solid lines, and arrows showing velocity.

Work 2

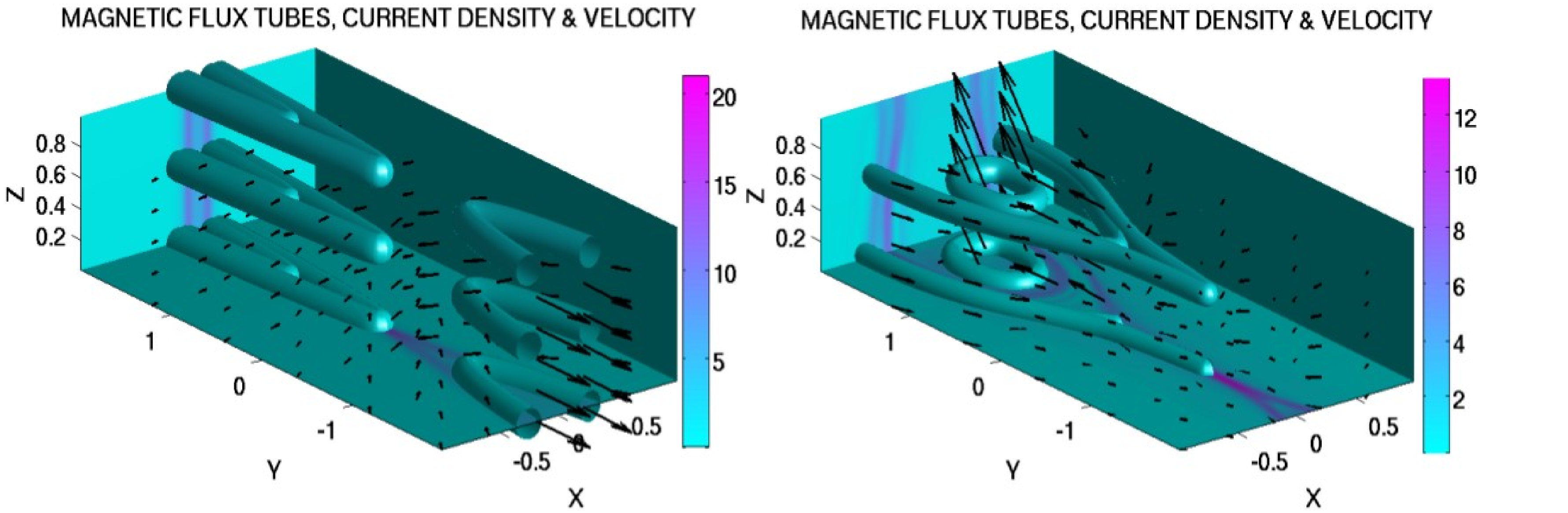

FIG. 3. Solutions in 3D in the first case, without the asymmetry in resistivity in the Z direction at T=30 (*Left panel*), and in the second case, with the asymmetry in the Z direction at T=70 (*Right panel*). Color grading is showing the toroidal current density at the boundary planes; tubes show a choice of the magnetic flux tubes, with the diameter of the tube set proportional to the magnetic field strength; arrows show velocity. A change in connectivity of the magnetic flux tubes in 3D, triggered by the asymmetry in resistivity in the vertical plane, additionally changes, and complicates, the topology of magnetic field.

Work 2

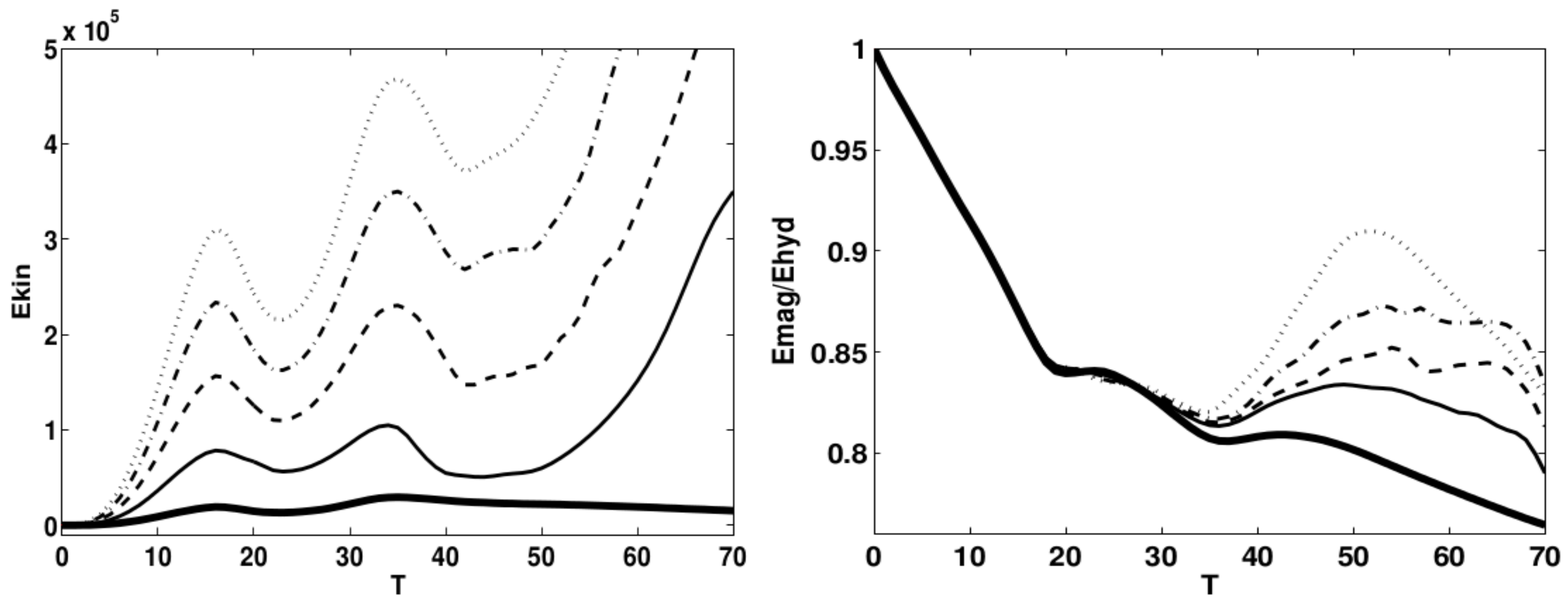

FIG. 4. Time dependence of the energy with different heights of the computational box in our simulations with reconnection in all three directions. In the *Left panel* is shown the kinetic energy, and in the *Right panel* is shown the ratio of magnetic to the sum of internal and kinetic energy. Results with different heights of the box h=1, 2, 3 and 4, are shown in solid, dashed, dot-dashed and dotted lines, respectively. In thick solid line is shown the result with height h=0.25 in the case with reconnection only in the X-Y plane, which is our reference 2D case. Kinetic energy during the build-up of reconnection is linearly increasing with height of the computational box, with the factor of proportionality about 2. The fraction of magnetic energy is steadily decreasing with time, until the reconnection in the third direction starts; then it increases proportionally with height.

Work 2

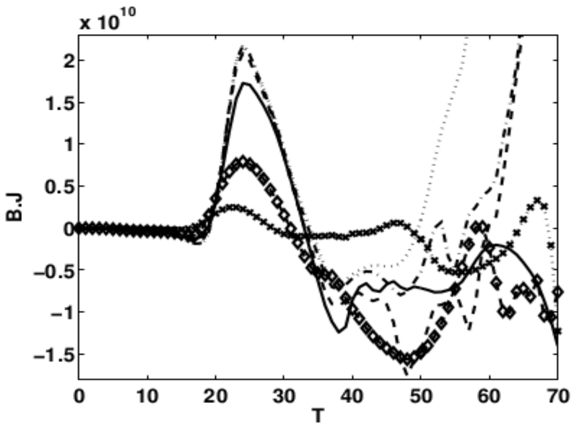

FIG. 5. Time evolution of current helicity in $X \leq 0$ half of the computational box. Results with different heights of the box h=0.25, 0.5, 1, 2, 3 and 4, are shown in black cross and diamond marked, solid, dashed, dot-dashed and dotted lines, respectively.

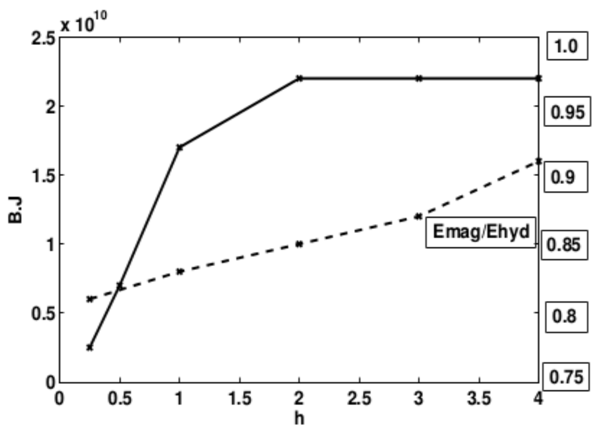

FIG. 6. In solid line is shown maximum variation in current helicity with height of the computational box, during the increase in reconnection. Values are taken from results at T=23, shown in Figure 5. In dashed line is shown the maximum variation of fraction of magnetic energy in dependence of h, taken from results about T=50 shown in Figure 4. Note the different scales in the vertical axes of the plot; the right side axis denotes the fraction of magnetic energy.

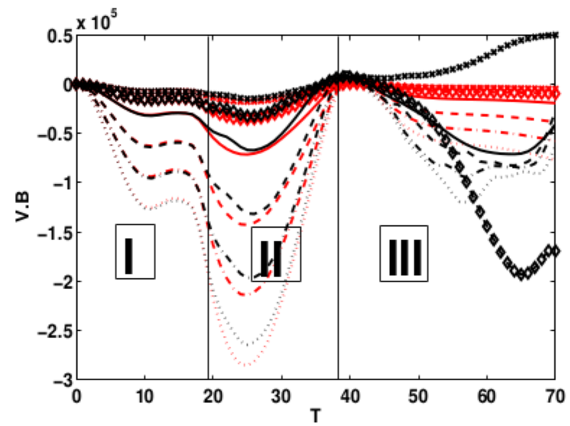

FIG. 7. Time evolution of cross helicity in $X \leq 0$ half of the computational box. Lines have the same meaning as in Figure 5. Results in the first case, with reconnection only in the X-Y plane, are shown in red lines, with the same line style coding. Three time intervals mark time of build-up of reconnection in the X-Y plane (I), increase in reconnection in the Z-direction (II), and short increase in the fraction of magnetic energy, during the re-organization of the magnetic field because of reconnection (III).

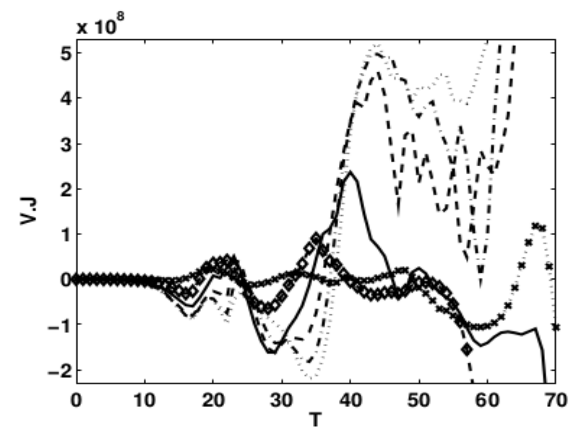

FIG. 8. Time evolution of "mixed helicity" in $X \leq 0$ half of the computational box. Lines have the same meaning as in Figure 5.

For any vector field $\boldsymbol{F}$, the quantity $\boldsymbol{F}\cdot(\nabla\times\boldsymbol{F})$ is called the helicity density. The integral over a closed volume is then the helicity. For a vector field which is invariant

Work 3: resistive jets

Resistive jet simulations extending radially self-similar magnetohydrodynamic models

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[2] *School of Cosmic Physics, Dublin Institute for Advanced Studies, 31 Fitzwilliam Place, Dublin 4, Ireland*
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ABSTRACT

Numerical simulations with self-similar initial and boundary conditions provide a link between theoretical and numerical investigations of jet dynamics. We perform axisymmetric resistive magnetohydrodynamic (MHD) simulations for a generalized solution of the Blandford & Payne type, and compare them with the corresponding analytical and numerical ideal MHD solutions. We disentangle the effects of the numerical and physical diffusivity. The latter could occur in outflows above an accretion disc, being transferred from the underlying disc into the disc corona by MHD turbulence (anomalous turbulent diffusivity), or as a result of ambipolar diffusion in partially ionized flows. We conclude that while the classical magnetic Reynolds number $R_{\rm m}$ measures the importance of resistive effects in the induction equation, a new introduced number, $R_\beta = (\beta/2)R_{\rm m}$ with β the plasma beta, measures the importance of the resistive effects in the energy equation. Thus, in magnetized jets with $\beta < 2$, when $R_\beta \lesssim 1$ resistive effects are non-negligible and affect mostly the energy equation. The presented simulations indeed show that for a range of magnetic diffusivities corresponding to $R_\beta \gtrsim 1$, the flow remains close to the ideal MHD self-similar solution.

Work 3: jets with large resistivity

Large resistivity in numerical simulations of radially self-similar outflows

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[2] *IASA and Section of Astrophysics, Astronomy and Mechanics, Department of Physics, University of Athens, Panepistemiopolis 15784 Zografos, Athens, Greece*

Received/Accepted

ABSTRACT

We investigate differences between an outflow in the highly-resistive accretion disk corona, and the results with smaller or vanishing resistivity. For the first time, we determine conditions at the base of a **two-dimensional** radially self-similar outflow in the regime of very large resistivity. **We performed simulations using the** PLUTO **magnetohydrodynamics code, and found three modes of solutions. The first mode, with small resistivity, is similar to the ideal-MHD solutions. In the second mode, with larger resitivity, the geometry of magnetic field changes, with a "bulge" above the super-fast critical surface. At even larger resistivities**, the third mode of solutions sets in, in which the magnetic field is not collimated any more, but is pressed towards the disk. This third mode is also the final one: it does not change with further increase of resistivity. Those modes describe topological change in a magnetic field above the accretion disk **because of the uniform, constant Ohmic resistivity.**

Key words: stars: pre–main sequence – magnetic fields – MHD – ISM: jets and outflows

Work 3

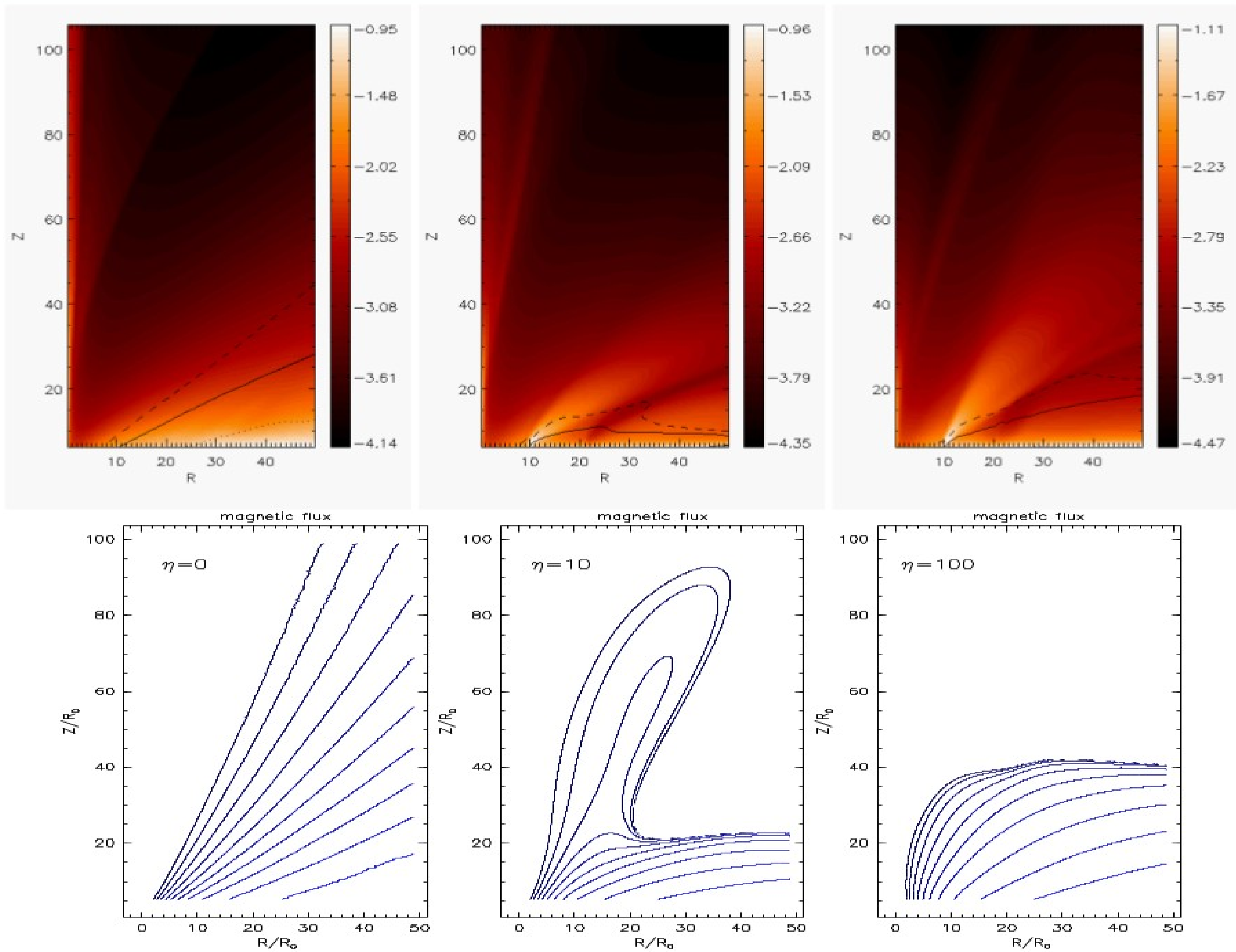

Figure 3. Illustration of the effect of resistivity on the density in the outflow. *Top panels*: In the *Left* panel are shown the quasi-stationary state solutions in the ideal-MHD case, and in the *Middle* and *Right* panels are shown solutions with large and very large resistivity, $\eta = 10$ and 100. Solutions with small resistivity are very similar to the ideal-MHD solution. Definitions of colors and lines are the same as in Figure 1. The obtained outflow for large and very large resistivity is supersonic in the entire domain, so that the slow magnetosonic surface is not present in those cases. *Bottom panels*: Magnetic flux isocontour lines with the above resistivities, $\eta = 0, 10, 100$ in the *Left*, *Middle* and *Right* panels, respectively. Contours are parallel to the poloidal magnetic field lines. With a small η, magnetic flux isocontour lines are of the same geometry as for the ideal-MHD case. We obtain three different geometries of solutions for small, large and very large resistivity. Topology of the magnetic field lines for corresponding values of resistivity is always similar to one of the three modes shown.

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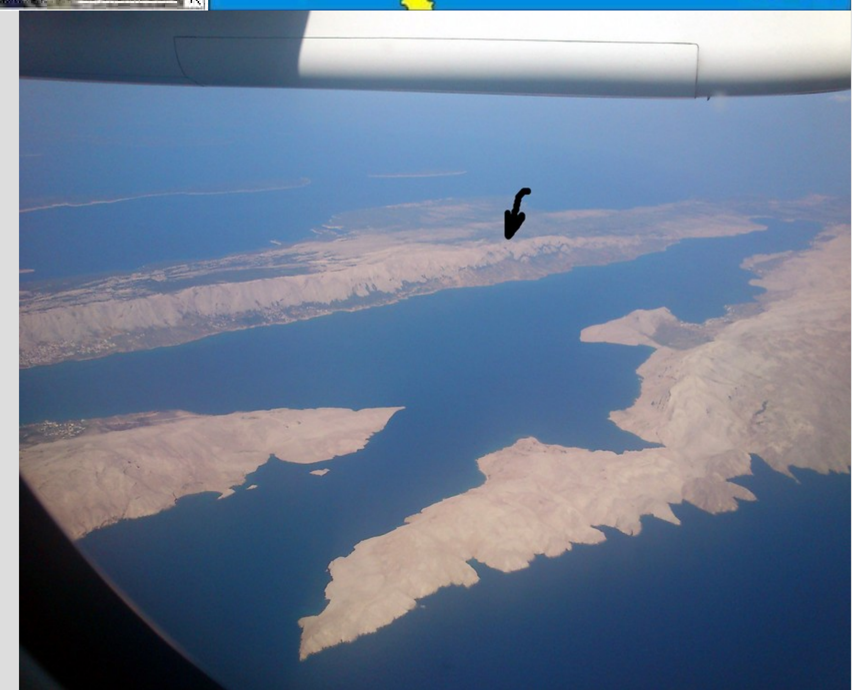

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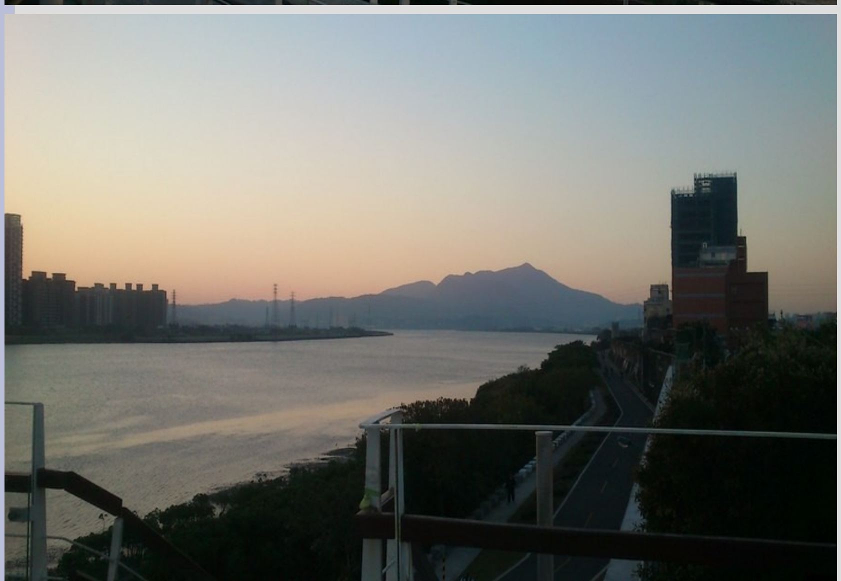

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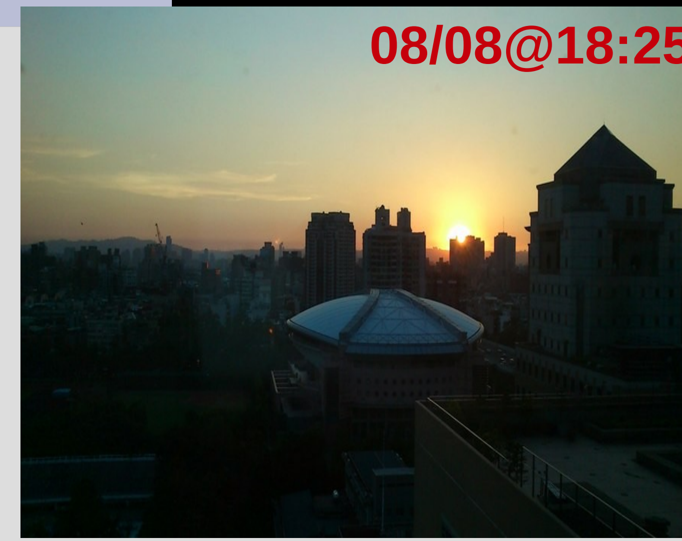
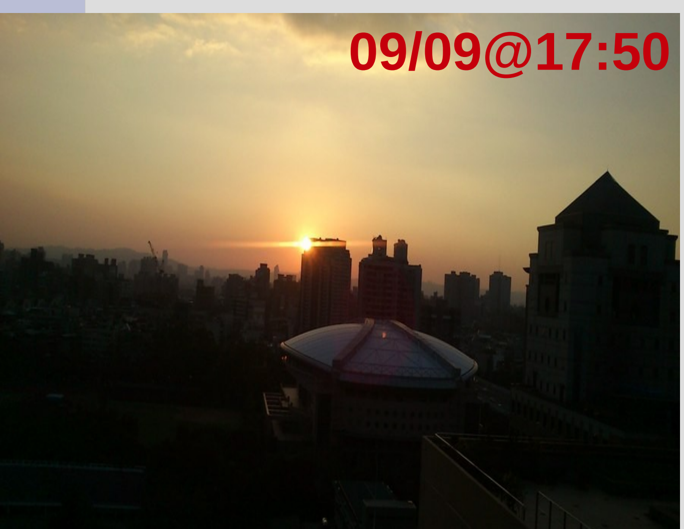
Sunsets

Sunsets 1

Sunsets 2





Sunsets 3

Sunsets 4

Taiwan & Life: May 25

So long, and...


THE HITCHHIKER'S GUIDE TO THE GALAXY
42
SO LONG, AND THANKS
FOR ALL THE FISH


DON'T PANIC