ISSI FINAL TEAM REPORT

1. Title of the Team project: **"Modeling cometary environments in the context of the heritage of the Giotto mission to comet Halley and of forthcoming new observations at Comet 67P/Churyumov-Gerasimenko"**

2. Objectives:

The project is dedicated to finding better insights on the problem of modeling the solar wind – cometary coma interaction. The emphasis is made on the fluid model approaches. The problem of the importance of the applied specific numerical techniques is also addressed. The basic aims of the project's activities are:
- Advance the understanding of the basic processes governing the interaction of solar wind plasma with the cometary coma.
- Comparing many different models of the global plasma interaction at comet environment.
- Reconsideration and possible reinterpretation of some experimentally observed but not uniquely explained phenomena in the comet Halley environment.
- Providing additional tools for possible interpretation of oncoming observation of the comet 67P/CG environment during the concluding stage of the Rosetta mission.

3. Dates of meetings:

First meeting: 19-23 November 2012

Presentations:
W.-H Ip: *"An Overview of Comet-Solar Wind Interaction at Different Length- and Time-Scale. Outline"*
M. Lebedev: *"Modeling the interaction between the solar wind and the atmosphere of a low gas-production comet with reference to the example of the Comet Grigg-Skjellerup";*
"Some possible phenomena on the night side of a comet in the solar wind flow"
M.Rubin, K. Altwegg, H. Balsiger: *"Theoretical and experimental studies on cometary dusty gas dynamics: overview and latest achievements devoted especially to the Rosetta mission" | movie1 | movie2*
S. McKenna-Lawlor *"Review, based on particles and fields observations made aboard the Giotto spacecraft, concerning the nature of the solar wind interaction with P/Halley and P/Grigg-Skjellerup"*; "Information on Mystery Boundaries"
A. Bhardwaj: ***"****Models for coma ionospheric species and chemistry. Electron Impact processes in the inner cometary coma";*
"Variations in the production rates and inhomogeneities of the inner coma. Causing mechanisms (observations and modeling). Impact on the large-scale dynamics"
K. Altwegg *"Results from the Giotto mission with respect to composition of volatiles.";*
Some expectations from the Rosetta Orbiter Spectrometer for Ion and Neutral Analysis ROSINA"
C. Koenders*:"Some recent experimental studies"; "MHD and hybrid approaches for modeling solar wind-ionized coma interaction";*
"Simulation of cometary jets in interaction with the solar wind"
M. Kartalev, M. Dryer, V. Keremidarska: *"Single fluid approaches for modeling solar wind-ionized coma interaction";*
"Prediction/interpretation of the boundaries in the inner ionized coma by single fluid gas-dynamic models."
C.-C. Wu, M. Dryer: *"Solar wind plasma/IMF connection to the comet missions"*
S. Ivanovski: "*Neutral and dust coma dynamics. Observations and modeling*"
S. Finklenburg**:** "*Modeling inhomogeneous gas and dust sources on comet nucleus. Comparison of ideal gas-dynamics solutions and a Direct Simulation Monte Carlo (DSMC) simulations*"
M. Rubin: "*Prediction/interpretation of the boundaries in the inner ionized coma by different modeling approaches | movie1 | movie2*;
"*Kelvin-Helmholtz instabilities at plasma boundaries. Possible implementation for magnetic cavity boundary* " *| movie1 | movie2*
S. Ivanovski, M. Kartalev**:** "*Kelvin-Helmholtz and tearing mode instabilities at plasma boundaries. Possible implementation for magnetic cavity boundary*"

Second meeting: 20 - 25 January 2014

Presentations:
W.-H Ip: *"Introductory lecture"*
D. Alexashov, V. Baranov and M. Lebedev: *"Magnetohydrodynamic model of the solar wind interaction with a cometary atmosphere"*
V. Baranov, M. Lebedev: *"The sorrow fate of the solar wind protons in the shock layer in the vicinity of the cometary ionosphere";*
V. Baranov: *"Interplanetary magnetic field penetration into cometary ionospheres*"
M. Rubin: *"Comet 1P/Halley multifluid MHD model for the GIOTTO fly-by";*
"Influence of material transport in the coma on the seasonal activity of comets";
"MHD-Hybrid code comparison for a weak comet";
"A Comprehensive Set of Comet Environment Models: The Inner Coma Environment Simulator (ICES)".
Ian Lai: *"Modeling cometary environments in the context of the heritage of the Giotto mission to comet Halley and of forthcoming new observations at Comet 67P/CG"*
M. Galand*:"Cometary ionosphere: comparison with planetary atmospheres in hydrostatic equilibrium";*
"The ionosphere of CG67P: characteristics and composition"
S. Ivanovski:*"Predictions on coma dust distribution. GIADA simulated measurements of 67P/C-G dust coma using different coma model prediction.";*
"Coupled Kelvin Helmholtz and tearing mode instabilities as a possible check for the position of the magnetic cavity boundary of comet 67P/CG"
T. Bonev**:"***Dynamical modeling of the DI dust ejecta cloud*"
C. Koenders**:** "*Hybrid Plasma Simulations of the Cometary Environmen";*
"RPC Measurements at Comet 67P/C-G".
M. Lebedev: *"Limiting regimes on the interaction between the solar wind and a cometary ionosphere"*
S. Nakov**,** M. Kartalev: *"On some aspects of the coupling of the inner neutral and ionized coma*"
C.-C. Wu: *"Global Three-Dimensional Magnetohydrodynamic Simulation Model";*
"I*nterpretation of the time intensity profile of solar energetic particles with global mhd simulation*".
S. McKenna-Lawlor: "*The scientific objectives of Rosetta and its Lander Philae*"

Third meeting: 29 September – 3 October 2014

Presentations:
V. Baranov, D. Alexashov**,** M. Lebedev: *"One-fluid MHD model of the solar wind interaction with the cometary atmosphere".*
C.-C. Wu: *"Evolution of three geoeffective Shock-CME pairs in September 2011"*
D. Alexashov, V. Baranov, and M. Lebedev. *"MHD simulation of flows from low-gas-production comets"*
Wing Ip: Special Issue on Earth, Moon and Planets "Active Cometary Atmospheres"
S. Ivanovski**:** *"Dynamics of aspherical rotating dust grains for GIADA experiment in the coma of 67P/Churyumov-Gerasimenko"*
M. Rubin: *"The activity of C-G at 3.5 AU from the Sun" ;*
"Heterogeneity of C-G: Preliminary results seen with Rosetta/ROSINA";
"First results of the volatile inventory at comet 67P/Churyumov-Gerasimenko from ROSINA DFMS"
K. Altwegg, M. Rubin: *"Rare species in Churyumov-Gerasimenko's coma"*
C. Koenders**:** *"The plasma environment of CG close to the perihelion";*
"On the weakly active comet"
M. Kartalev, S. Nakov: *"Revisiting some simple models of the inner cometary atmosphere"*
Ying Liao*: "3-D DSMC Simulations of Comet 67P/Churyumov-Gerasimenko"*
Wing Ip**:** *"Cometary ion acceleration process"*
M. Galand: *"The effect of dust on the ionosphere of 67P"*
S. Raghuram: **"***Atomic oxygen and CO Cameron band emissions in comets"*
S. McKenna-Lawlor: "Remotely-Sensed Solar Wind Analysis and Forecast at the Rosetta Spacecraft and *Comet 67P/C-G"*
R. Marschall**:** *"Gas and dust simulations for CG"*

4. Participants:

Team members:

Murray Dryer, NOAA Space Weather Prediction Center, Boulder , Colorado;
Susan McKenna-Lawlor, Emeritus Professor at the National University of Ireland, Maynooth and Director of Space Technology;
Wing-Huen Ip, National Central University, Graduate Institute of Astronomy, Chung-Li, Taiwan;
Vladimir Baranov, Head of the laboratory in The Institute For Problems in Mechanics, Russian Academy of Science, Moscow;
Michail Lebedev, Department of Numerical Mathematics, Moscow State University;
Martin Rubin, University of Bern, Switzerland;
Mehdi Benna, Solar System Exploration Division, NASA Goddard Space Flight Center, Greenbelt, Maryland, USA;
Monio Kartalev, Institute of Mechanics, BAS, Sofia, Bulgaria

Invited experts:

Kathrin Altwegg, Space Research & Planetary Sciences Division at the University of Bern;
Hans Balsiger, Space Research & Planetary Sciences Division at the University of Bern;
Anil Bhardwaj, Space Physics Laboratory, Vikram Sarabhai Space Centre, India;
Chin-Chun Wu, Naval Research Laboratory, USA;
Marina Galand, Imperial College London, UK;
Susarla Raghuram, Imperial College London, UK;
Tanyu Bonev, Institute of Astronomy, BAS, Sofia, Bulgaria

Young scientists:

Stavro Ivanovski, Institute for Space Astrophysics and Planetology, Rome, Italy;
Christoph Koenders, TU Braunschweig, Germany;
Susanne Finklenburg, Space Research & Planetary Sciences Division at the University of Bern
Svetoslav Nakov, St. Kliment Ohridski University, Sofia, Bulgaria;
Ian-Lin Lai, Institute of Space Science National Central University Jhongli, Taiwan
Ying Liao, PhD student, University of Bern;
Raphael Marshall, PhD student, University of Bern.

5. Assessment of the Team activities; highlights:

1. Detailed review of the development of the theoretical models of comet-solar wind interaction before and after the spacecraft explorations of comet Giacobini-Zinner and comet Halley in the 80s.
2. A comprehensive comparison of hydrodynamical approximations of the cometary gas outflow and shock structures with those obtained by most up-to-dated MHD and hybrid kinetic calculations.
3. Thorough discussions of the solar wind interaction of comet 67P at different heliocentric distances.
4. Theoretical analysis and numerical simulation of the formation of the diamagnetic cavity and inner shock structure in the cometary ionsphere.

5. Review of cometary ion acceleration processes observed in the vicinities of comet Halley, Giacobini-Zinner, and Griggs-Skellup, respectively.
6. Examination of the interaction of solar storms like solar flares, coronal mass ejection and solar energetic particle events with comet 67P.
7. Comprehensive review of the cometary neutral gas coma chemistry and energetics from photolytic effects.
8. Innovative investigation of new types of ion composition and dust-plasma interaction of 67P.
9. Detailed modeling of cometary aeronomy related to the optical emission of CO Cameron bands as diagnostic tool of the CO abundance.
10. Reports on the new results from the plasma and gas measurements from the Rosetta mission.

The activities in the above problems involved not only members of the team, but also wider groups of scientists in their universities or institutes. Especially should be emphasized attracting many young scientists - including several PHD student from the University of Bern.
Following are brief descriptions of the achievements of some different groups (as viewed by themselves), obtained during the project and to some extent influenced by the activities of the Project.

* Several members of the ISSI group, University of Berb, have been engaged in modeling the plasma environment of comet 1P/Halley. One subgroup used a multifluid MHD approach for the plasma environment of comet 1P/Halley. Previous space missions such as ESA's Giotto fly-by at Halley provided a rich data set which we used to validate our model (Rubin et al. 2014a). Based on these simulations the multifluid MHD model could be compared to Hybrid-type simulations and applied to Rosetta target comet 67P/Churyumov-Gerasimenko (Rubin et al. 2014b). The obtained results are ingested in the planning cycle of the scientific investigations by the Rosetta Plasma Consortium (RPC) and Rosetta Orbiter Spectrometer for Ion and Neutral Analysis (ROSINA) instrument teams on Rosetta. We have also performed simulations of the neutral gas an dust environment of comet 67P/C-G: namely we studied the redeposition of gas and dust on the comet's surface. The focus was to investigate changes in the comet's activity when trapped volatiles are (thermally) released from areas that come only into sunlight after equinox passage. (Rubin et al. 2014a,b,c)

* The main task in the science planning for the Rosetta Plasma Consortium (RPC, TU Braunschweig) is the prediction of positions of structures and boundaries in the plasma environment at comet 67P/Churyumov-Gerasimenko. Only if these positions are meaningful, the measurements of the interesting physics by the RPC instruments are possible, and not only by change. Thus, an intensive comparison of the used models is required. Since our ISSI group gathers a broad knowledge on numerical cometary plasma simulations, intensive discussions on the different models, their predictions and their limits took place during our meetings. As a result a series of papers which discussed the different stages of the cometary plasma environment at the Rosetta's target comet and the structures and boundaries therein has been published.

* 3D One-Fluid MHD Model of the Solar Wind Interaction with Cometary Atmospheres was developed by Moscow group. The processes of photoionization of the neutral component of the comet matter and the resonance charge exchange between charged and neutral particles are taken into account, together with the interplanetary magnetic field effect. The adequacy of the single-fluid MHD approximation in describing the plasma flow with different temperatures of the components is shown. The model is numerically realized on the basis of the higher-order Godunov method using an approximate solution of the arbitrary MHD discontinuity breakdown. The results of a numerical investigation of the plasma and magnetic field parameters in the vicinity of a comet are presented for the conditions corresponding to the flyby of several spacecraft near the comet Halley in March 1986 and the expected fly-round of the comet Churyumov--Gerasimenko by the Rosetta spacecraft in 2015.

Interplanetary Magnetic Field Penetration to Cometary Ionospheres: Under physical conditions of cosmic space (including the solar wind) the cyclotron frequency of electrons is almost always much greater than the frequency of their collisions. In this case the plasma electro-conductivity is anisotropic relative to the magnetic field direction, Hall currents can be important and the condition for magnetic field freezing in the plasma can not be correct. It is shown that the equation of the magnetic field induction taking into account Hall currents can give rise to the magnetic field penetration through tangential discontinuities into unmagnetized plasma. A formula for the thickness of penetration regions is given. Using this formula the depth of the interplanetary magnetic field penetration into the coma of comet Halley is estimated equal 25 km. This value coincides with measurements obtained by magnetometer on the board of spacecraft Giotto during comet Halley missions in 1986 (see

Neubauer, 1988). The thickness of the interplanetary magnetic field penetration in the coma of the comet Churyumov-Gerasimenko in the perihelium (November 2015) is predicted equal 20k

* The interaction of low-activity comets with the solar wind was studied with reference to case of Grigg—Skjellerup comet on the basis of the MHD single-fluid model developed by Moscow University group. The results obtained were compared with those earlier obtained on the basis of a purely hydrodynamic model, as well as with the results calculated in Benna & Mahaffy's study using a multi-fluid MHD model. The three simulations though based on somewhat different physical models and using different numerical approaches, provide fairly similar results and the same, though slight, discrepancies with the measured data obtained onboard the Giotto spacecraft during its flyby past the GS comet in June 1993. These discrepancies can be attributed to the deficiencies of hydrodynamic models in the case of low gas-production comets. The calculations were also carried out for the expected conditions at different points of Rosetta's orbit when approaching the Sun. It was shown that there exists a limiting solution for the case in which the comet gas production tends to zero, if certain dimensionless similarity variables are used.
A simple model is proposed which allows the density fields of the solar wind protons and the heavy ions of the cometary origin (picked-up ions) to be separated from the common density field calculated within the framework of the single-fluid model. The method is based on the assumption that the velocities of both components are the same. The density fields thus obtained ahead of and behind the bow shock are analyzed and compared with the density profiles measured with various instruments onboard the Giotto spacecraft during its flyby near the Halley comet in 1986 and calculated on the basis of more complicated multi-fluid models. It is shown the results obtained are in satisfactory agreement.

* An unique situation exists for Rosetta mission in the interpretation of data obtained very near the comet nucleus. Variations in the data caused by both the external condition and the movement of the spacecraft plus the rotation of the nucleus, made difficult the application of developed in the literature models for idealized situations. The Sofia group revisited and modified some simple inner coma models aiming the development of some possible "quick look" data interpretation algorithms. Earlier developed by this group gasdynamic models of solar wind-ionized coma interaction could be useful in possible interpretation of the 67P magnetic cavity region.

* During the active period of the ISSI team #248, The Imperial College group have assessed the effect of dust grains on the ionospheric state of 67P at perihelion. In that purpose, we have added the presence of grains from a few nanometers to a few hundreds of nanometers, in our ionospheric model which was originally developed for a pure gas phase. Free electron and ion attachments to the grains have been taken into account along with photoelectron emission from uncharged grains and photo detachment of electrons from negatively-charged grains. Our study has benefited from valuable discussion within the team regarding possible constrains to be obtained from Rosetta measurements and the validity of the approach applied for dusty plasma conditions. Our findings have been submitted to Icarus for publication. The beneficial discussions within the team supported by ISSI are acknowledged in the manuscript.

* The overview and recent results on aspherical dust dynamics for GIADA experiment aboard of ESA ROSETTA mission (Institute for Space Astrophysics and Planetology, Rome) have been discussed. Studying the neutral dust coma with the forthcoming results of ROSETTA data contributes the knowledge of the 67P cometary environment in the closer vicinity.
Results were reported from MHD numerical simulations of the coupled Kelvin-Helmholtz (KH) and tearing mode (TM) instability applied to a cometary context. An ab-initio model has been earlier introduced for simulating MHD instabilities on the dayside earth magnetopause layer. We used numerical scheme utilized in time-dependent two-dimensional approach for solving incompressible MHD equations with three dimensional velocity and magnetic field vectors and with magnetic and fluid viscosities included. The focus is on deriving conditions which: 1) lead to the development of the most intensive twin-vortex structures due to the electric current systems and 2) represent the physical image on the magnetic cavity in the case of comet 67P/Churyumov- Gerasimenko. The inferred instabilities could be candidates for causing mechanism of experimentally observed transient events such as the traveling convective vortices, detected in the ionosphere and on the ground. We believe that in a cometary context, the appearance of these instabilities can be used for determining the location of the magnetic cavity. This work has been presented at the meeting "Planetary Science Perspectives in Italy" at Italian Space Agency on 3-4 June 2014 in Rome. This work will be a subject of a near future paper for the special issue of "Earth, Moon and Planets"Journal.

* Space weather can potentially strongly affect the environment of Comet 67P/Churyumov–Gerasimenko and, thereby, the scientific measurements made aboard ESA's accompanying Rosetta Spacecraft. Ongoing forecasting of the remotely-sensed solar wind at the comet using an interplanetary scintillation (IPS) technique has thus been instituted by Space Technology Ireland, Ltd in co-operation with B. Jackson of the University of California in San Diego to endure from the time of the initial reconnaissance phase of Rosetta about the comet nucleus (early August-2014) until December 2015 (i.e. until after the comet

has passed its closest point to the Sun in August 2015). This monitoring of the cometary environment is working well with interesting responses recorded by several instruments aboard Rosetta at the predicted times of solar disturbances.

* Another aspect of the Space weather influence on the comet environments were considered by NRL, USA group. A possible implementation of CME models were demonstrated on the example of modeling geomagnetic storms, recorded in September 2011. A global, three-dimensional (3-D) magnetohydrodynamic (MHD) numerical model with inputs based on actual solar observations (e.g., speed of the CME) is used to simulate the response of the 3-D heliosphere. Velocity pulses were used to simulate CMEs' evolution from near the Sun to the Earth environment for a period of September 03-30, 2011. More than 15 CMEs were observed in September 2011. The related 15 solar disturbances (or CMEs) were injected into the lower boundary at 2.5 solar radii (RSUN). We have successfully simulated these CMEs' evolution from Sun to the Earth. Simulated solar wind parameters (velocity, density, magnetic field, and temperature) are matched well with 1 AU in-situ observation from Wind spacecraft (orbiting around L1). Three simulated IP shocks arrival time at 1 AU are also matched with the observation. It is found that background solar wind is an important factor on the propagation of IP shocks and CMEs. The simulation results are also useful for explaining "How the magnetic holes were formed behind the IP shocks?".

* The scientists of the Project were informed about the recent modeling efforts of the Planetary Imaging Group, University of Bern in collaboration with the Institute of Space Science National Central University, Taiwan. 3-D DSMC Simulations of Comet 67P/Churyumov-Gerasimenko**,** as well 3-D Simulations of the Inner Gas and Dust Comae of a Proxy for Comet 67P/Churyumov-Gerasimenko were reported and discussed.

6. Outcome in relation to the objectives:

Our ISSI team initiated a **Special Issue "Active Cometary Atmospheres"** of the Journal **"Moon, Earth and Planets".** The team members Wing-Huen Ip and Susan McKenna-Lawlor are the guest editors of this Issue. After the discussion at the ISSI team meeting at Bern, Switzerland, we have now a set of ten abstracts for potential manuscripts:

1. Kartalev, M. et al., 3D gas dynamics model of solar wind-comet atmosphere interaction
2. Raghuram et al., Prediction of CO Cameron band and atomic osygen forbidden emissions of 67P/Churyumov-Gerasimenko
3. Marschall, R., Y. Liao, et al., 3D simulations of the inner gas and dust comae of a proxy for comet 67P/Churyumov-Gerasimenko
4. Wu, C.C. et al., Heliospheric plasma sheet crossing of comet 67P
5. Ivanoski, S., MHD instability at the ionospheric cavity boundary
6. Rubin, M. et al., Prediction of comet-solar wind interaction of comet 67P inside 2 AU
7. Mckenna-Lawlor, S., et al., Space weather effects at comet 67P
8. Baranov, V. and Lebedev, V., , Hydrodynamic model of comet-solar wind interaction
9. Ip, W.-H., Lai, I.L. and C.-E., Wei, Multi-species coma dynamics and chemistry of comet 67P
10. Lai, I.L., Rubin, M. and Ip, W.-H., Solar wind interaction of comet 2013 A1 Siding Spring at Mars

Besides these articles, we plan to solicit additional contributions from other colleagues. The manuscripts submission deadline is January 15, 2015.
In addition, numerous publications of members of the team, acknowledging ISSI, are already published or accepted for publication (listed in the next point).

7. Publications resulting from the Team work: (only publications resulting from the team work including acknowledgment to ISSI)

Wing-Huen Ip. „Estimates Of the Size Of the Ionosphere Of Comet 67P/Churyumov-Gerasimenko during Its Perihelion Passage in 2014/2015. Chapter article in a monograph to be published by Springer: "Planetary Exploration and Science: Recent Results and Advances" Editors: Shuanggen Jin, Nadar Haghighipour, and Wing-Huen Ip.

M. Rubin, N. Fougere, K. Altwegg1,, M. R. Combi, L. Le Roy, V. M. Tenishev, and N. Thomas1 MASS TRANSPORT AROUND COMETS AND ITS IMPACT ON THE SEASONAL DIFFERENCES IN WATER PRODUCTION RATES, The Astrophysical Journal, 788:168 (8pp), 2014a June 20

C. Koenders, K.-H.Glassmeier, I.Richter , U.Motschmann, M.Rubin, Revisiting cometary bow shock positions. Planetary and Space Science, Volume 87, p. 85-95. 2013

M. Rubin, M. R. Combi, L. K. S. Daldorff, T. I. Gombosi, K. C. Hansen, Y. Shou, V. M. Tenishev, G. Toth, B. van der Holst, and K. Altwegg, COMET 1P/HALLEY MULTIFLUID MHD MODEL FOR THE *GIOTTO* FLY-BY. The Astrophysical Journal, 781:86 (13pp), 2014b February 1

D. B. Alexashov, V.B. Baranov, and M.G. Lebedev. 3D MHD model of the solar wind interaction with comet atmosphere. (accepted) Fluid Dynamics Izvestija RAN, MZHG No 1, 2015.

V.B. Baranov, M.G. Lebedev. Density distribution of the solar wind protons and the “loaded” cometary ions in the shocked region in front of the comet ionosphere. Astronomy Letters (accepted)

M. Rubin, C. Koenders, K. Altwegg, M.R. Combi, K.-H. Glassmeier, T.I. Gombosi, K.C. Hansen, U. Motschmann, I. Richter, V.M. Tenishev, G. Tyth. Plasma environment of a weak comet – Predictions for Comet 67P/Churyumov–Gerasimenko from multifluid-MHD and Hybrid models. Icarus 242 (2014c) 38–49.

Vigren, E., M. Galand, P. Lavvas, A.I. Eriksson, and J.-E. Wahlund (2014), On the possibility of significant electron depletion due to nanograin charging in the coma of comet 67P/Churyumov-Gerasimenko near perihelion, Ap. J., under review

М.Г. Лебедев. „Газодинамическая модель взаимодействия солнечного ветра с йоносферой кометы применительно к условиям сопровождения кометы Чурюмова-Герасименко космическим аппаратом „Розетта”. Труды академических чтений по космонавтике, Москва, Январь 2014, Стр.138

D.A. Alexashov, V.B. Baranov, and M.G. Lebedev. A new MHD model of the solar wind / cometary ionosphere interaction. COSPAR, MOSCOW, 40th Scientific Assembly, 2 – 10 August, 2014, Program Book, B0.4-0042-14, p. 313

W.-H. Ip and Martian Rubin cooperate on a joint paper describing the plasma environment and energetic ions and neutral atoms (ENA) in the vicinity of comet C/2013 A1 Siding Spring during its close encounter with Mars on October 19, 2014. (in preparation)

W.-H. Ip and Susan McKenna-Lawlor will edit a special issue on “Active Cometary Atmospheres” for publication in “Moon, Earth and Planets”. (in preparation).

S. Nakov , K. Grigorov, M. Kartalev. “Modeling inner cometary atmosphere“; interactive web-based tool for remote automated model running. http://geospace4.imbm.bas.bg/comet/