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INTERSTELLAR PROBE — WHERE IS THE "NOSE" OF THE HELIOSPHERE?

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ABSTRACT. In this paper are reviewed publications that were concerned about the discovery of the location of the heliopause "nose" by the Newtonian Approximation method and publications using the full three-dimensional magnetohydrodynamic simulations of the heliosphere that confirmed that discovery.

Since we do not have a clear answer to the question of what the heliosphere looks like, in connection with the planned launch of the Interstellar Probe within this decade, there was a problem with deciding which direction to send it. The discovery of the movement of the "nose" of the heliopause depending on the direction of the interstellar magnetic field and the determination of the position of the "nose" is very important for this decision. Therefore, the purpose of the article is to answer the question of where is the "nose" of the heliopause.

In the second part of the article, the possibility of changing the paradigm of scientific research projects related to interstellar missions (including those focused on the study of the heliosphere), among other things, by increasing the interdisciplinarity of research, is explored. As part of initiating such cooperation, the article develops social sciences themes related to the sustainable logistics of Interstellar Probe missions to increase public involvement in these projects.

Keywords: heliosphere, heliosphere model, interstellar probe, paradigm shift, space logistics

1. INTRODUCTION

Our Star is one of a hundred billion stars in the Galaxy that moves through interstellar gas, plasma, and dust formed from supernova remnants and stellar astrospheres. From the Sun flows the solar wind (SW), creating a huge cavity called the heliosphere, in the incoming interstellar material containing the planetary system with the Earth on which we live. Beyond the heliosphere, the unexplored Local Interstellar Medium (LISM) represents a whole new area that is critical to SW's interaction with LISM and offers the key to understanding our home in the Galaxy.

Over the course of more than six decades, numerous and sophisticated models of the heliosphere have been developed, in which attempts were made to take into account not only the global interaction between the SW plasma with the ionized and neutral component of the LISM, but also known processes occurring in the SW, which influence the structure and shape of the heliosphere. In the meantime, valuable empirical data were also obtained that created a new reality for the heliosphere modeling process. The major Voyager 1 (V1) and 2 (V2) space missions since their launch in 1977 have been providing SW data. In the last 18 years, Voyager missions have provided additional data of intersection of the termination shock (TS) by V1 in 2004 at the distance of ~94 AU and by V2 in 2007 at the distance of ~84 AU from the Sun. LISM regions, close to the boundary of the heliosphere, the heliopause (HP), have been reached by V1 in 2012 at the distance of 119 AU and V2 in 2018 at the distance of 122 AU from the Sun. Both Voyagers have discovered beyond the HP new paradigms in space physics, but they will most likely be able to send data only until 2027 or 2028 (Richardson et al., 2022).

Therefore, the scientific world returned to the idea of sending an interstellar mission (Brandt et al., 2018, 2019, 2022; McNutt et al., 2019, 2022), which began to be thought about 60 years ago. The Interstellar Probe (IP) is a mission concept to study the mechanisms that shape our heliosphere and is the first step not only beyond the HP, but also into a heliosphere-undisturbed interstellar cloud. Extensive engineering requirements have been put in place to achieve this goal, which include being ready to launch IP no later than January 1, 2030, capable of transmitting scientific data from 1,000 AU and ensuring a probe life of not less than 50 years. To travel so far and so fast, the spacecraft's speed should be at least twice that of Voyager 1, i.e., 7.2 AU/year (McNutt et al., 2022).

However, since we do not have a clear answer to what the heliosphere looks like, as evidenced by its six different shapes in Figure 1 (Ratkiewicz et al., 2006; Pogorelov et al., 2015; Opher et al., 2015; Dialynas et al., 2017; Opher et al., 2020; Reisenfeld et al., 2021), there is a problem with deciding in which direction to send the probe. To find an answer to this question, it should help the discussion on the so-called “nose” of the HP.

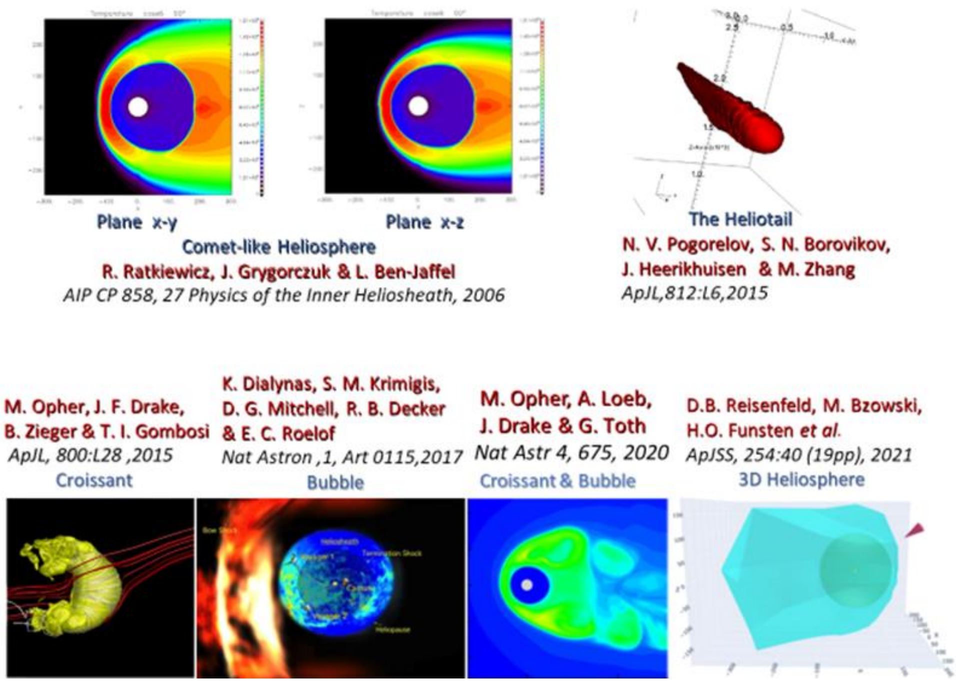


Figure 1. Different heliosphere shapes from numerical results: Comet-like Heliosphere, the Heliotail, Croissant, Bubble, Croissant and Bubble, and three-dimensional map of the heliosphere from IBEX

In this article at Sections 2–4 are reviewed publications that were concerned about the discovery of the location of the HP “nose” by the Newtonian Approximation (NA) method (Banaszkiewicz and Ratkiewicz, 1989; Fahr et al., 1986, 1988; Ratkiewicz and Banaszkiewicz, 1989) and publications that confirmed that discovery (Izmodenov and

Alexashov, 2015; Ratkiewicz et al., 1998, 2000; Zirnstein et al., 2016). On that basis is how the answer to the question in the title of this article has been discussed. Such a problem was not discussed in other publications but is mentioned in this article.

Nowadays, scientists from other scientific disciplines should also be involved in the search for such answers. Cooperation with them may initiate a paradigm shift in science and research projects related to space missions. In this article at Section 5, this problem is discussed from the viewpoint of a social sciences representative.

2. THE NEWTONIAN APPROXIMATION METHOD

Based on the assumption that the HP is a pressure equilibrium surface separating two types of counterflowing plasma — SW and LISM — the influence of the LISM magnetic field on the shape of the heliosphere can be investigated using the NA method. The main idea of this method is the assumption about the interaction of highly supersonic magnetized plasma. In both fluids, the two shock waves are then close to each other, so that their shape and the separating surface's shape between them are approximately the same (Figure 2). The NA serves as a simple recipe to calculate in an approximate way the forces used in the pressure balance equation that defines the HP: namely, the forces that are calculated from the unperturbed tensors. In this way, the problem of finding a solution for the shape of the HP becomes decoupled from the problem of solving the flow from the full set of magnetohydrodynamic (MHD) equations, described in the next section.

The intersection of HP with the axis through the center of the Sun and parallel to the LISM velocity vector is referred to as the "nose" of HP.

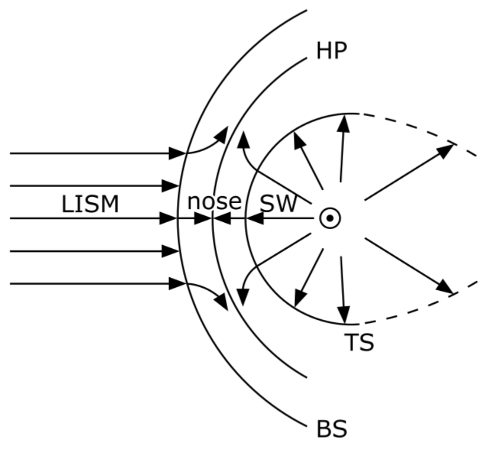


Figure 2. The "nose" of the HP

Knowing the physical parameters of both undisturbed plasma, and using the NA approach, we are calculating the shape of the HP (Fahr et al., 1986). Assuming that thermal pressure in plasma is isotropic, the total pressure tensor (being a sum of thermal, ram, and magnetic pressures), known as Reynolds–Maxwell stress tensor, is in the following form:

$$\Pi_{ik} = p\delta_{ik} + \rho v_i v_k - \left(B_i B_k - \frac{B^2\delta_{ik}}{2}\right)/4\pi \tag{1}$$

where δ_{ik} is Dirac delta, p is pressure, ρ is density, v is velocity, and B is magnetic field. Within the NA principle, the normal components of the pressure forces $\Pi_{ik}N_i$ acting on the HP are required to be equal. This then leads to the following equation:

$$\{\Pi_{ik}N_i N_k\}_{SW} = \{\Pi_{ik}N_i N_k\}_{LISM} \tag{2}$$

where the suffixes SW and LISM denote solar wind and interstellar plasma conditions. Equation (3) can be written as:

$$\left(\rho Vn^2 + p + \frac{B^2}{8\pi} - \frac{Bn^2}{4\pi}\right)_{SW} = \left(\rho Vn^2 + p + \frac{B^2}{8\pi} - \frac{Bn^2}{4\pi}\right)_{LISM} \tag{3}$$

where the suffix n in equation (3) means the normal component.

The solution of the equation (3) describes the shape of HP and only the HP as discussed above. It should be emphasized once again that according to the main idea of NA, the LHS and RHS of basic equation (2) are to be evaluated for the unperturbed stress tensors of the corresponding plasma fluids, i.e., the tensors describing the fluids as if being unaffected by the presence of the boundary.

3. RESULTS OF THE NEWTONIAN APPROXIMATION APPROACH

The results obtained with the NA method showed the deviation of the HP "nose" from the direction of the LISM inflow by an angle θs and the dependence of this deviation on the angle between the LISM velocity vector and the direction of the ISMF vector, called the inclination angle (Figure 2, Fahr et al., 1986). Note that in the current version of the paper, we have three different designations for the angle of inclination: α, θo, and Ψo, which results from the review of various papers.

The formula for the dependence of the angle of deviation θs on the inclination angle θo was precisely derived by Fahr et al. (1988) and has the form:

$$\theta_S = \frac{1}{2}\,\mathrm{arctg}\,\frac{-\sin\theta o}{M_A^2 - \cos\theta o} \tag{4}$$

Dependence θs of the interstellar magnetic field strength is expressed in this formula by the Alfvén Mach number M_A=Vis/V_A, where Vis is LISM velocity and $V_A=\frac{B}{\sqrt{4\pi\rho}}$ is Alfvén velocity vector. In Figure 3, continuous curves are for M_A>1, straight line for M_A=1, dashed curves for M_A<1.

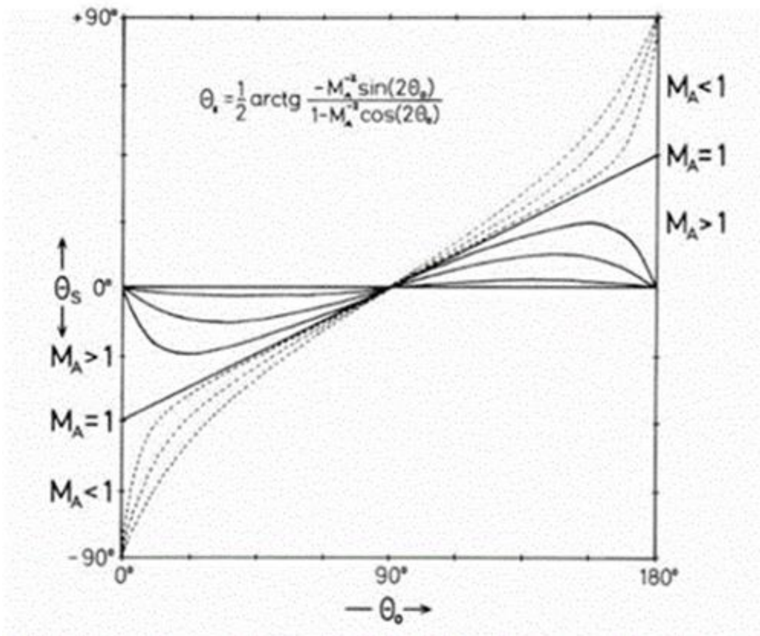


Figure 3. Dependence of the angular deviations θs of the HP "nose" for different inclination angles θo and different Alfvén Mach numbers (M_A) (Fahr et al., 1986, 1988)

In Figure 4, the shape of HP for inclination angles Ψo=0°, 30°, 60°, 90° (note that θ_0 in Figure 3 corresponds to Ψo in Figure 4) is shown by lines: yellow, red, green, and blue, respectively. For these inclination angles, the "nose" deviation is θs=0°, -23°, -13°, 0°, respectively, and distances r from the Sun: r~280 AU, r=232 AU, r=208 AU, r=190 AU, respectively. The number M_A=1.15>1. In Figure 3, the continuous curve for values θ_0=0° and 90° takes value θs=0°. For inclination angles 0°<θ_0<90°, the absolute value of θs reaches maximum. The function θs at Figure 3 explains deflection angle values in Figure 4.

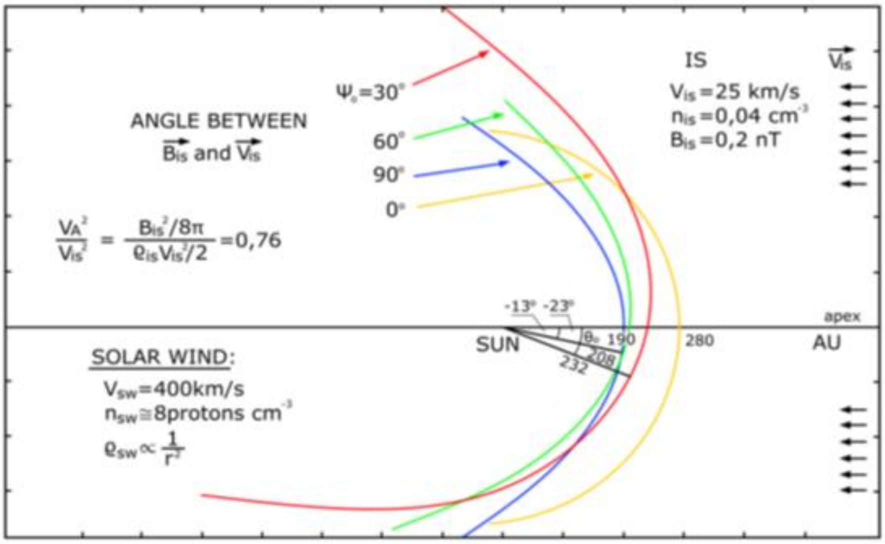


Figure 4. Shape of the HP in the plane Bis-Vis that contains the LISM velocity and magnetic field vectors for different inclination angles Ψo (Fahr et al., 1986, 1988)

Results of the NA approach did not only discover the HP "nose" deviation, but also confirm in this way a great importance of the ISMF in the SW–LISM interaction.

4. RESULTS OF MAGNETOHYDRODYNAMIC SIMULATIONS OF THE HELIOSPHERE

As was mentioned in the previous section, the problem of finding a solution for the shape of the HP using NA approach became decoupled from the problem of solving the flow from the full set of MHD equations.

Results of the full three-dimensional MHD model of the SW interaction with LISM (without taking into account the internal magnetic field) confirmed the existence of HP "nose" deviation (Ratkiewicz et al., 1998). Due to the full MHD model for the first time has shown the structure and shape of the heliosphere for any inclination angle, it turned out that the heliosphere deviates together with the HP in the same direction, and the shock wave in the interstellar plasma (called the bow shock) also deflects, but in the opposite direction (Figure 5).

Numerical simulations showed that the ISMF field lines draping around the HP are most compressed in the quasi-perpendicular direction to the unperturbed LISM magnetic field direction (Figure 6). The heliosphere asymmetry caused by the ISMF is illustrated in Figure 7, which shows thermal isobars in the three coordinate planes, x-y, x-z, y-z, for the inclination angles 0°, 67°, 90°. First, note that in MHD simulation without the inner magnetic field, the heliosphere is symmetrical in the x-y plane, which is the Bis-Vis plane. When the ISMF is parallel to the LISM velocity, the heliosphere is axisymmetric in the x-axis (Figure 7A). In the case of perpendicular magnetic field (Figure 7B), the asymmetry is essentially a flattening of the heliosphere, as may be seen in Figure 7 (Bb and Bc, compare also Cb).

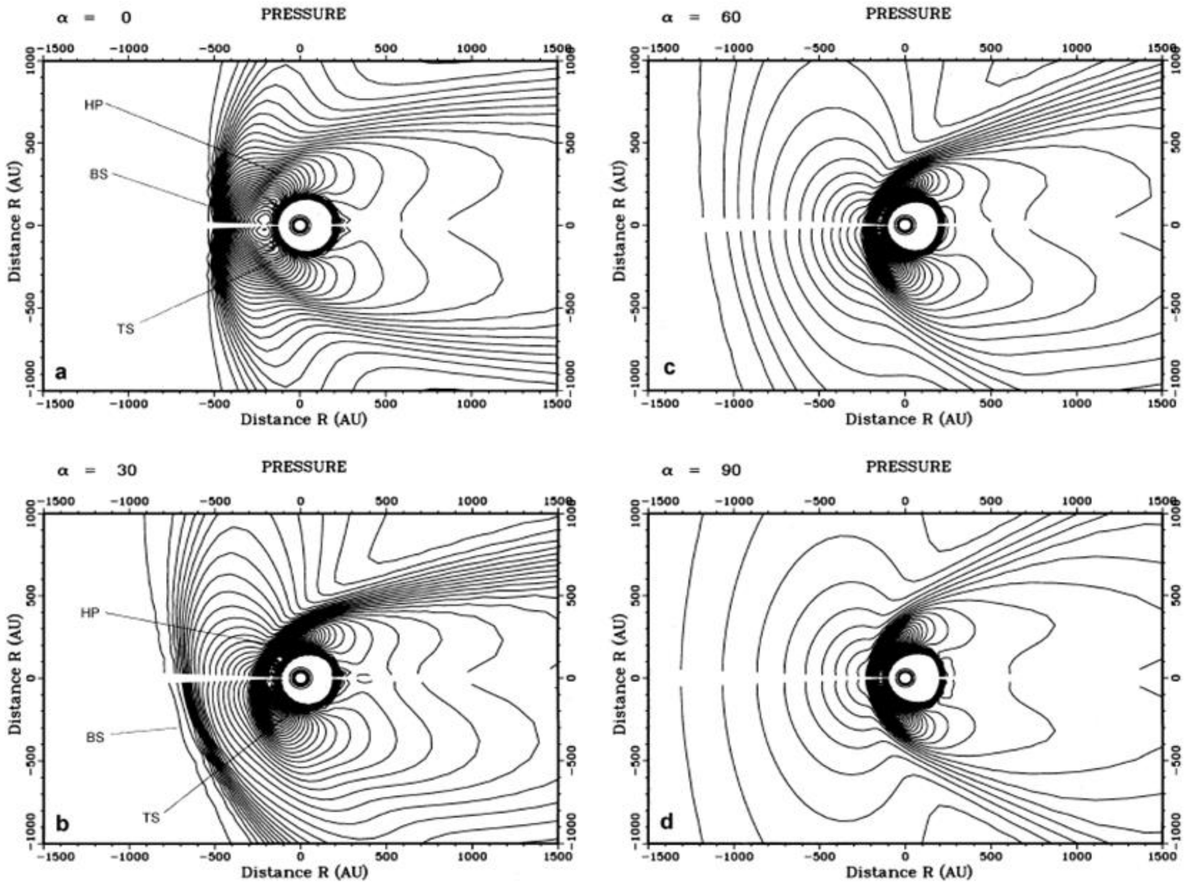
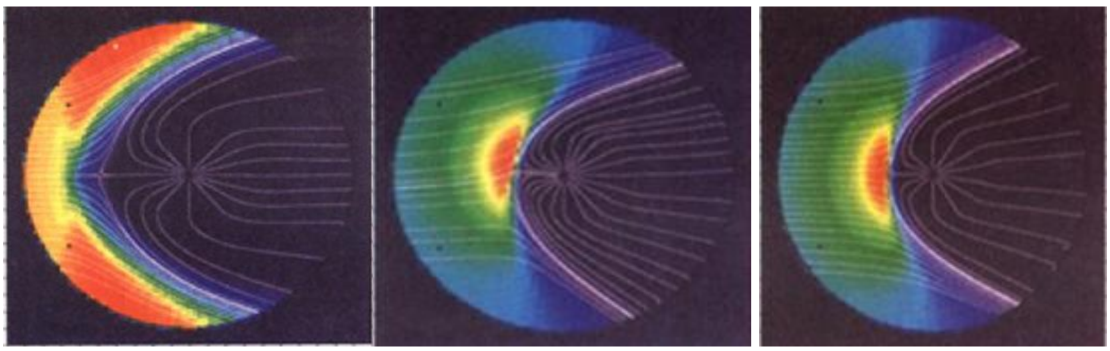


Figure 5. Shape of the boundary region as shown by thermal pressure contour plots for inclination angle α equal to a. 0°, b. 30°, c. 60°, d. 90°. VLISM Alfvén Mach number=1.5. Position of termination shock (TS), HP, and bow shock (BS) is indicated in the left panel (Ratkiewicz et al., 1998).

a b c

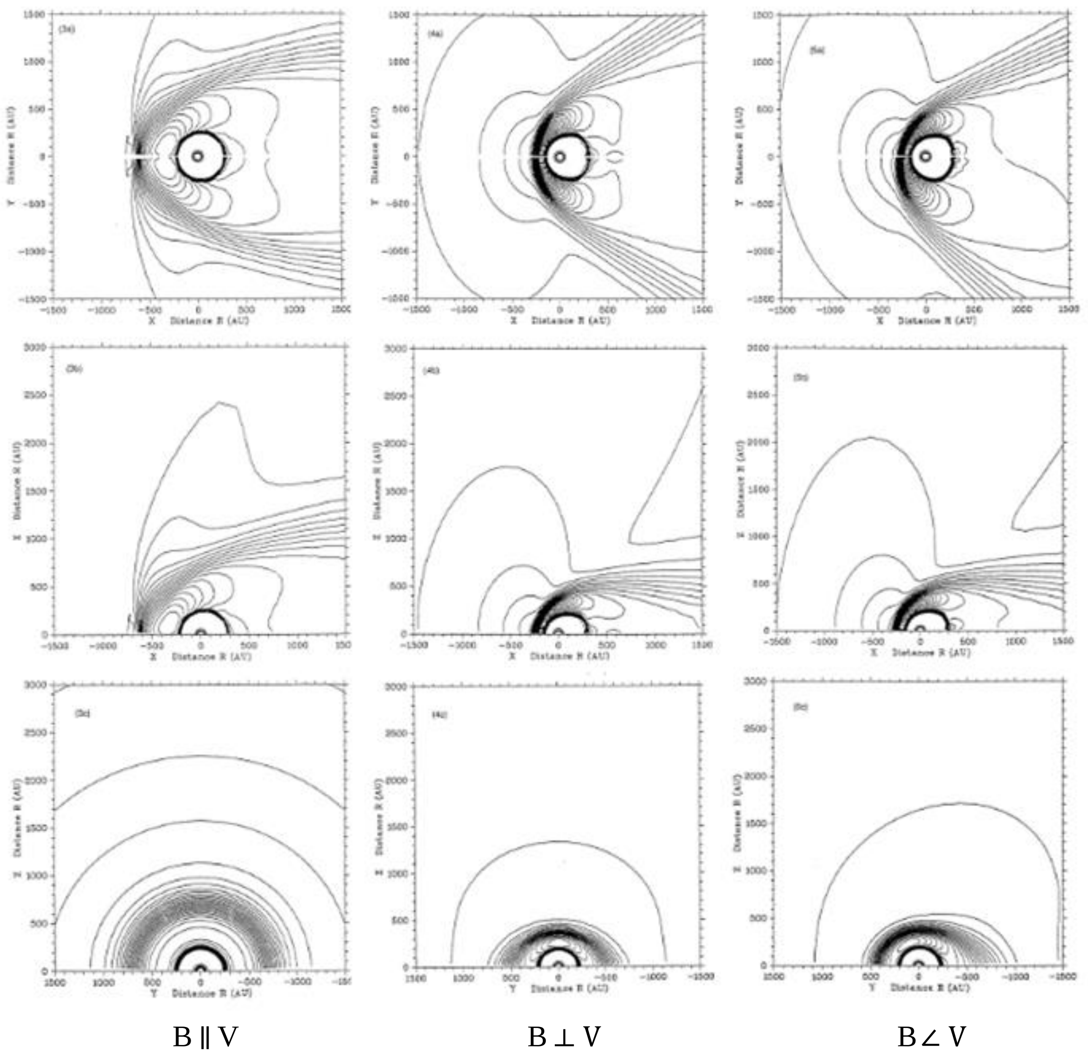


B ∥ V B < V B ⊥ V

Figure 6. Magnetic field pressure for ISMF inclination angle α equal to a. 0°, b. 67°, c. 90°. The ISMF pressure reaches its maximum (red) in the quasi-perpendicular direction to the unperturbed LISM magnetic field direction (Ratkiewicz et al., 2000).

The case of oblique magnetic field is illustrated in Figure 7C. In the x-y plane (Figure 7Ca), "noses" of the HP (with TS) and bow shock are displaced from the x-axis and in opposite directions. This is an effect of the asymmetric draping of the magnetic field lines around the HP. The field lines are oblique to the flow direction and they are mostly compressed on the quasi-perpendicular direction on side of the heliospheric "nose" (compare Figure 6b). In general, the "nose" of the HP is most displaced in the direction of the most compressed magnetic field, where the magnetic field pressure attains its maximum (Figure 6). Simultaneously, the effective magnetosonic Mach number in this region is reduced, so that the bow shock becomes weaker, as discussed earlier, and moves away from the Sun (Ratkiewicz et al., 1998). On the other side of the HP "nose," the scenario is the opposite; little or no magnetic field is added to the thermal pressure (see Plates 1b–1d, Ratkiewicz et al., 1998) and the effective Mach number is not reduced. This is why the "noses" of the bow shock and HP are displaced in opposite directions. This tilting mechanism is manifested globally as a distortion in the y-z plane (Figure 7Cc).

A B C



B || V B ⊥ V B∠ V

Figure 7. Thermal isobars in three coordinate planes, x-y, x-z, y-z, for inclination angles 0°, 67°, 90° show axisymmetric heliosphere (column A: parallel interstellar velocity and interstellar magnetic field

vectors) and asymmetric heliosphere (column B: deviation in x-y plane, flattening in x-z and y-z planes for perpendicular ISMF and (column C: deviation in x-y plane, flattening in x-z plane, and distortion in y-z for oblique ISMF) (Ratkiewicz et al., 2000).

The results of MHD simulations (Ratkiewicz et al., 1998, 2000) in relation to the “nose” of the heliosphere were confirmed in Figure 3 in the article by Izmodenov and Alexashov (2015), where at panels A and B are plasma streamlines and isolines of the plasma density normalized to the proton density in LISM. At panels C and D are magnetic field lines and isolines of the magnetic field magnitude in dimensionless units. Left panels (A and C) correspond to a model without interplanetary magnetic field (IMF), while right panels (B and D) correspond to a model with IMF. All the panels are made in the z-x plane determined by the interstellar velocity and magnetic field vectors.

The answer to the question posed in the title of our publication is perfectly illustrated in Figure 8 (=Figure 3, Izmodenov and Alexashov, 2015). The absolute maximum ISMF pressure is reached in the region just behind the HP (Figure 8C, D). The angle between the LISM velocity vector and the line connecting the center of the Sun to the point of maximum pressure of the ISMF shows the deviation of the “nose” of the HP. Therefore, we should look for the “nose” of the HP in the place where the pressure of the interstellar magnetic field is the greatest.

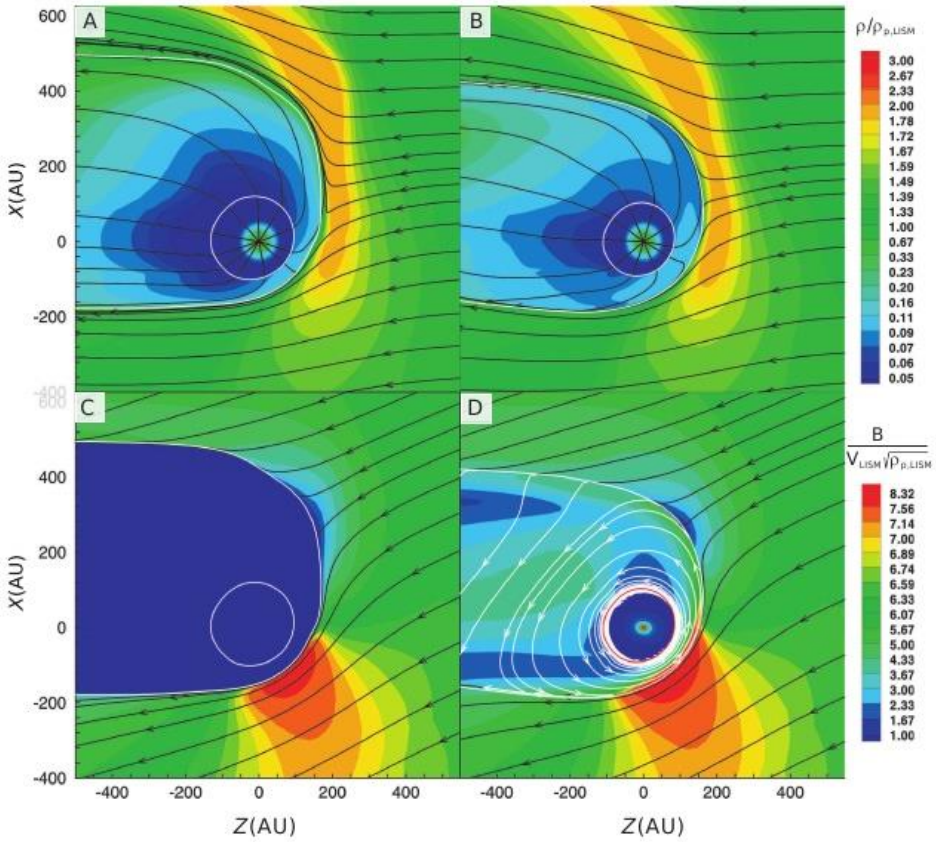


Figure 8. Perfect confirmation of the deviation of the HP “nose” applies both to the heliosphere model without IMF (left panels) and with IMF (right panels) (*courtesy* Izmodenov and Alexashov, 2015).

Another confirmation of the HP “nose” tilt as described in both Section 3 and Section 4 can be found in Figure 9, which is Figure 1 in the article by Zirnstein et al. (2016). In this figure are isocontours of the ribbon Energetic Neutral Atoms (ENA) production rate outside the HP denoted by five colors distinguishing the ENA energies. The background color represents the magnetic field magnitude, with some ISMF lines (black curves). Suprathermal ions outside the HP become neutralized by charge exchange (blue circles) and form ENAs that may travel back inward toward IBEX (gray lines). (*courtesy* Zirnstein et al., 2016).

The Figure 9 contains all the elements illustrating the heliosphere's "nose" deviation. In particular, it shows the formation of a "tongue" with gray lines perpendicular to the ISMF line, where the maximum of field is reached on this line.

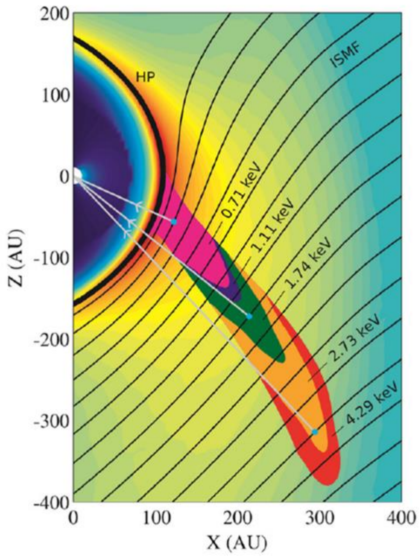


Figure 9. The created "tongue" is set towards the maximal ISMF on each line at right angles (blue circles) (*courtesy* Zirnstein et al., 2016).

5. A PARADIGM SHIFT IN RESEARCH PROJECTS RELATED TO INTERSTELLAR MISSIONS

The planned launch of the IP in the next decade is an excellent rationale for undertaking mission-supporting science projects, including making them more interdisciplinary. What in the practice of today's space missions is an important element determining their success, for example, logistics, economics, ecology, or communication with the public, should have a greater participation in scientific work related to space missions, including the IP.
The current science paradigm related to reaching a close interstellar center has been in force since the beginning of human space exploration. Until the Voyager data became available, heliosphere studies had theoretical foundations. However, for several decades, space probes such as V1 and V2 or other projects focused on studying space have provided real data allowing for new discoveries. Moreover, many changes occurred in scientific research projects on Earth during the Voyager's long journey. Now is the time to answer the question: Does the current paradigm for interstellar missions fit the changing world?

Doubts that appear in the scientific discourse regarding the current models of the heliosphere, the enormous amount of time and money needed to carry out heliospheric missions, the intimate and exclusive nature of this type of initiative, with the simultaneous intensification and popularity of space projects within the three bodies (Earth, Moon, Mars), are the reasons why sending the next IP may not meet with a positive response from decision-makers or the public. The described factors (anomalies) give reasons to consider a paradigm shift in research projects concerning the heliosphere. As part of this shift, we should open up to new dynamic models of the heliosphere (created or verified by the participation of artificial intelligence), build, and test them during sustainable space missions within an interdisciplinary community of scientists, and include the public (humanity) in the team. The new paradigm can accomplish the following mission: "*Let interstellar missions become Earth-friendly projects for all humanity, and IPs become the eyes of every human in space*."

The diagram of the paradigm shift along with the factors (anomalies) causing this change is shown in Table 1.

Table 1. Paradigm shift in interstellar research projects (missions)

Elements of the paradigm	The "old paradigm" of heliospheric research missions	Anomalies and other factors influencing the paradigm shift	The "new" paradigm of heliospheric research missions
The heliosphere modeling approach	Traditional Based on theoretical data Scientific discussion on current models of the heliosphere	Voyager probes reaching heliospheric boundary and real data availability The development of artificial intelligence	Modern Based on theoretical and empirical data Building or verification and testing of models as part of space missions and using modern technologies, such as artificial intelligence
Interstellar mission priorities	Designing space probe missions to ensure the greatest possible number of measurements and data Single missions for which individual support systems are built (logistics, engineering, research, and management team)	Serious social and environmental problems on Earth (pandemic, climate crisis, social crisis, social inequalities) Growing ecological awareness of the society and social pressure for sustainable development Criticism of high spending on research projects by the public, decision-makers as well as among scientists	Sustainable interstellar missions with mainly scientific goals, but also environmental, social, and economic goals Campaign missions that use available mission management systems, including logistics systems
Character and composition of research teams	The research teams are mainly composed of scientists in the fields of physics, astrophysics, and astronomy, as well as engineers	The growing interest of scientists from other fields in space exploration Increasing complexity of space missions Pressure on the effectiveness of research projects	Research teams are interdisciplinary They are composed of scientists from various fields who support the mission and benefit from its effects, integrating heliosphere research into the achievements of their fields

Elements of the paradigm	The “old paradigm” of heliospheric research missions	Anomalies and other factors influencing the paradigm shift	The “new” paradigm of heliospheric research missions
Communication of research projects with society/social involvement	Communication of research projects with the social environment reduced to short media information or information provided by government agencies (such as National Aeronautics and Space Administration) on their websites Little public transparency of research projects No social involvement	Development of communication technologies The overabundance of data and information available on the web, making it difficult for the public to focus on research projects related to interstellar missions The very long duration of interstellar missions and their high cost and risk Intensive promotional activities for space projects within the three bodies (Earth, Moon, Mars) and focusing on social attention in this area	Creating information and image campaigns and broad promotion of research projects Including social and environmental goals in research projects Building intellectual capital for future missions High transparency of research projects and open access to data High social involvement

In the following part of the article, the topics related to the sustainable logistics of IP missions and the increase of social involvement in these projects will be developed.

5.1. Sustainable logistics of interstellar probe missions

The work on a new heliosphere model may contribute to the development of new theories in many fields of science which, in turn, may have a significant contribution to the scientific progress in the area of research projects related to outer space exploration. Social sciences represent one of such areas and logistics is included within their framework that belongs to the discipline of management and quality sciences. The experience gained by outer space logistics after more than six decades of supporting the presence of a human being in space allows developing a new logistics model for interstellar space missions, changing the form of a one-off mission to a campaign-oriented one (Ho et al., 2014) and putting more emphasis on balancing the scientific, social, economic, and environmental goals.

Outer space logistics stands for the theory and practice of managing the flow of materials, services, and information for the purposes of achieving the goals of the outer space system (Snead, 2004). Within the framework of outer space logistics, the activities dedicated to both space projects and systems are carried out in outer space and on Earth, with their goal being the maximization of the exploration potential resulting from the space vehicle performance, the efficiency and effectiveness of processes, and also for infrastructure capacity.

The progress made by the practice of outer space mission logistics is not that extensive in terms of theory. It is true that the logistical support for outer space missions has been known in science since the very beginning of human activity in space; however, this problem has been developing primarily as the element of flight engineering, and in the source literature related to social sciences where it practically does not exist at all.

A preliminary source literature review indicates that outer space logistics is mainly discussed in the area of orbital missions or the missions within the Earth–Moon–Mars system (Ishimatsu et al., 2016), which allows identifying a significant scientific gap in the logistics of interstellar missions. In order to eliminate this gap and also to ensure the development of interstellar missions, especially by increasing their efficiency, effectiveness, and safety, it is justified to undertake more extensive research into their logistical support.

The intensity and scale of space projects imposes a change in the perception of outer space logistics. The development of individual logistics systems for each subsequent mission is associated with high costs and low performance, and also has a negative impact on the environment. It is, therefore, postulated to replace single, timely logistics systems with a permanent, flexible logistics network connecting terrestrial and outer space cells, however, focusing mainly on the flows in space (Ho et al., 2016). In addition, due to the significant impact of outer space projects on life on Earth, it is postulated that the logistics, as their part, presented a more sustainable nature (Shull et al., 2006).

Based on the modeling of space logistics for current space logistics systems, the logistics model for interstellar missions will allow increasing the effectiveness and efficiency of these advanced scientific research projects. At the same time, this model should take into account the changes taking place in the society, economy, and natural environment of the Earth, which means that it should be a sustainable one in its assumptions. The task facing scientists in the field of social sciences is therefore to develop a model for the sustainable logistics of interstellar missions.

5.2. Increasing social involvement in interstellar research missions

Interstellar missions represent costly, complex, and long-term research projects, which do not produce immediate effects and, therefore, may raise objections of the decision-makers, the public, and even certain scientific circles. While planning unmanned space missions, primarily the longer range ones, scientists and engineers focus on the typical limitations: limit of the achieved flight speed, the weight limit of the transported equipment, knowledge gaps regarding the conditions prevailing in outer space, difficulties related to the durability of measuring devices, and communication limitations. The issues of social acceptance or involvement are predominantly approached as the external determinants over which the researchers have no influence (McNutt Jr et al., 2019). Meanwhile, many projects, especially those carried out at the beginning of space exploration, were implemented precisely as a result of public interest, which was manifested in political and business decisions, and also an extremely intensive development of intellectual capital and technological innovations.

The subject matter of social interest and involvement in outer space projects is relatively rarely discussed in the scientific literature. The modest output available through the search engines consists of two publications under the same editorship (Kaminski, 2019 and Kaminski 2021) and the niche articles covering. More advanced activities related to the identification of the provided information effectiveness are taken up by the space agencies, primarily National Aeronautics and Space Administration (NASA) (NASA, 2013). As shown by the experience of space agencies, appropriate communication and promotion of the scientific and research projects do increase their social acceptance, interest, and involvement. This, in turn, can support the improvement of their effectiveness through generating positive responses of the decision-makers as well as developing both intellectual capital and innovation for the needs of space missions.

6. CONCLUSIONS

In the context of the planned space mission of sending for the first time in human history the IP to a distance of 1000 AU from the Sun, we presented a review of publications related to the movement of the HP "nose" discovered in the 1980s.

The deviation of the "nose" of the HP from the inflow direction of the local interstellar medium is closely related to a decision in which direction to send the IP.

The main issues presented in this work are as follows:

1) survey of publications about discovery of the "nose" of the HP made by the simplified method of NA;
2) confirmation, by three-dimensional MHD models of the heliosphere, the dependence of this deviation on the direction and strength of the interstellar magnetic field;
3) demonstration, referring to the work of Izmodenov and Alexashov (2015), that points to whether or not the heliosphere model takes into account the IMF.

It should be noted that the three-dimensional MHD models of the heliosphere (Ratkiewicz et al., 1998, 2000) focused on studying the SW–LISM interaction to obtain the shape and structure of the heliosphere, which allowed to directly confirm the deviation of the "nose" of the heliosphere, depending on the interstellar magnetic field (Figures 5 and 6 in this paper). In the paper by Izmodenov and Alexashov (2015), the authors focus on the effects of the heliospheric magnetic field and on the heliolatitudinal dependence of SW, and not at the "nose" of the HP. Nevertheless, Figure 3 (Izmodenov and Alexashov, 2015, the same as Figure 8 in this paper) is a confirmation that the deviation of the HP "nose" depends on the direction of the interstellar magnetic field. In the article by Zirnstein et al. (2016), which is devoted to a different topic than the HP "nose", the maximum pressure of the interstellar magnetic field at the HP occurs on lines perpendicular to the interstellar magnetic field lines (Figure 1, Zirnstein et al., the same as Figure 9 in this paper), and this fact is related to the deviation of the HP "nose" (compare Figures 5 and 6 in this paper).

Thus, in all these publications, we find the answer to the question posed in the title of this article. The nose of the HP always faces the maximum intensity of the interstellar magnetic field.

In the second part of the article, the possibility of changing the paradigm of scientific research projects related to interstellar missions (including those focused on the study of the heliosphere), among other things, by increasing the interdisciplinarity of research, is explored. As part of initiating such cooperation, the article develops social sciences themes related to the sustainable logistics of IP missions to increase public involvement in these projects.

In the next publication, we will present the results for MHD models of the heliosphere with isotropic solar wind, fast and slow solar wind, with or without the internal magnetic field.

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