ROLE OF MAGNETOSPHERIC PLASMA PHYSICS FOR UNDERSTANDING COSMIC PHENOMENA

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Abstract

Cosmic phenomena occur in the remote regions of space where in-situ observations are not possible. For proper understanding of these phenomena laboratory experiments are essential, but the in-situ observations of magnetospheric plasma provides even a better background to test various hypothesis of cosmic interest. This is because the ionospheric-magnetospheric plasma and the solar wind are the only cosmic plasmas accessible to extensive in-situ observations and experiments.

1. Introduction :

Astrophysical or astronomical phenomena occur in the remote regions of the universe where in-situ observations are not possible. They involve matter in extreme states of temperature and/or density usually in a magnetised plasma state. Since in-situ diagnosis of cosmical objects is not possible, our understanding of astrophysical phenomena will depend critically on the reliability of interpretational techniqes of obervational data.

Our nearby environment is dominated by three ordinary states (viz.solid, liquid and gas). However, on the cosmic scale the situation is just opposite. Almost all the matter in the universe is in plasma state. The nearest shore of this cosmical plasma ocean is located in our own near space environment. The near space environment comprising ionosphere-magnetosphere of Earth and nearby interplanetary space provides a rich variety of naturally occuring plasma : cool, weakly ionised, collision dominated, gravity confined plasma as well as hot, fully ionised and virtually collisionless, magnetically confined plasma. Although there is enormous difference in linear scales as well as time scales involved in the working of astrophysical/cosmical systems and near space plasma, a careful extrapolation of results to cosmic scales have been successfully used to explain many distant cosmic phenomena. The theoretical studies in conjunction with the in-situ investigations of easily accessible magnetospheric plasma provides a more reliable

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background to test various hypothesis of cosmic physics. This is why astrophysics has made many remarkable discoveries during the last few decades with the development of highly shophisticated space science and technology.

2. Cosmic physics via magnetospheric research :

For proper understanding of astrophysical phenomena theoretical interpretations of observational data relying on certain simplifying assumptions must be guided by some emperical knowledge of how the real plasma behave in nature. It is in this context that the significance of magnetospheric plasma research can not be ignored. The terrestrial ionosphere-magnetosphere can be regarded as a sample of the more distant astrophysical/cosmical plasma. History of magnetospheric research amply illustrates how the in-situ observations of magnetospheric plasma have dramatically changed our perceptions of cosmic phenomena. We will discus here only few examples.

The early magnetospheric physicists regarded magnetosphere as essentially collisionless with infinitely large conductivity and hence unable to support magnetic field-aligned potential drops/electric fields. However,subsequent spacecraft measurements have proved beyond doubt that this is not true. The significance of magnetic field-aligned electric currents and fields is the realisation that the classical concept of frozen-in-magnetic filed has only limited validity. The frozen-in-magnetic field concept previously used to be a fundamental postulate of cosmic electrodynamics. As a consequence of violation of frozen-inmagnetic field concept existence of magnetic field-aligned potential drops/electric fields becomes a reality. There are several mechanism which can support such field-aligned electric fields viz. anomalous resistivity, collisionless thermo-electric effect, magnetic-mirror effect and potential double layers (Falthammar, 1978).

All known astrophysical plasma is magnetised. This plasma is typically of low density i.e. the mean free path being much larger than the scale size of the phenomena considered and hence electric currents flow essentially along magnetic field lines which is usually inhomogeneous. Thus, conditions favourable for formation of double layers and magnetic-mirror supported electric fields may not be very uncommon in cosmical plasmas. This will have a very far reaching consequence. Many explosive events observed in cosmic physics such as magnetic substorm, solar flare (releasing energy of the order of

10^{22}W), double radio sources (emitting power of the order of 10^{35}W) can be attrributed to double layer formations. Some flare star radio outbursts contain orders of magnitude more power than a solar flare but the time scale and high degree of polarisation suggest that the basic mechanism may be similar (Spangler and Moffet, 1976). Similarly a model for pulsar emission due to Sturrock (1971) based on two-stream instability observed in geomagnetosphere is capable of explaining the γ-and X-ray bursts observed from Crab pulsar (Kennel, 1975). Of interest to this pulsar emission model are the mechanism of sheath particle acceleration and current driven plasma wave instability which is very common in magnetosphere. Filamentary structures so abundantly observed in cosmic plasmas (interstellar clouds, interstellar medium, cometary tails, magnetic flux ropes, solar prominences, spicules, coronal streamers etc.)can also be attributed to field-alig-currents. Alfven (1981) provides an excellent treatise on these problems.

Space explorations have found number of boundary layers separating regions of different magnetisation, density, temperature, electron density and even chemical composition such as magnetopause, magnetotail sheet, heliospheric equatorial sheet etc. Since such properties can not be attributed to only those regions of space which are accessible to man made spacecrafts, one can reasonably assume that the interstellar and intergalactic space, in general have a cellular structure. As a consequence of this cellular structure of space one can conclude that the cosmic space is divided into large number of cells. Then the demand for symmetry is satisfied only if half of these cells are filled with ordinary matter while other half contains antimatter separated by the socalled Leidenfrost layers (Lehnert, 1977). However, size of such structures is difficult to derive theoretically and impossible to observe directly with the present day science and technology.

An important but puzzling problem in astrophysics is how the energetic (sometimes extremely energetic) radiations are produced and matter is accelerated to very high velocities (sometimes approaching the velocity of light).

Cosmic ray particles with energies upto 10^{19} eV or more have been observed. Advances in γ- and X-ray astronomy have demonstrated existence of large number of astrophysical objects emitting high energy photons. Some of these acceleration/energisation mechanism responsible for cosmic radiation/galactic cosmic rays can be studied in the magnetosphere. Figure 1 taken from Alfven (1981) gives a survey of some important plasma phenomena in laboratory and cosmos.

3. Conclusion:

Results of magnetospheric plasma research have led to drastic revision of views on cosmic plasma. As nature believes in simplicity, one can assume that the basic properties of plasma to be the same everywhere from laboratory to cosmos. Radio emissions from solar chromosphere and corona and from cosmic plasma beyond our solar system are the result of the same plasma wave processes. Hence, efforts should be made to put all the available knowledge in a unified framework.

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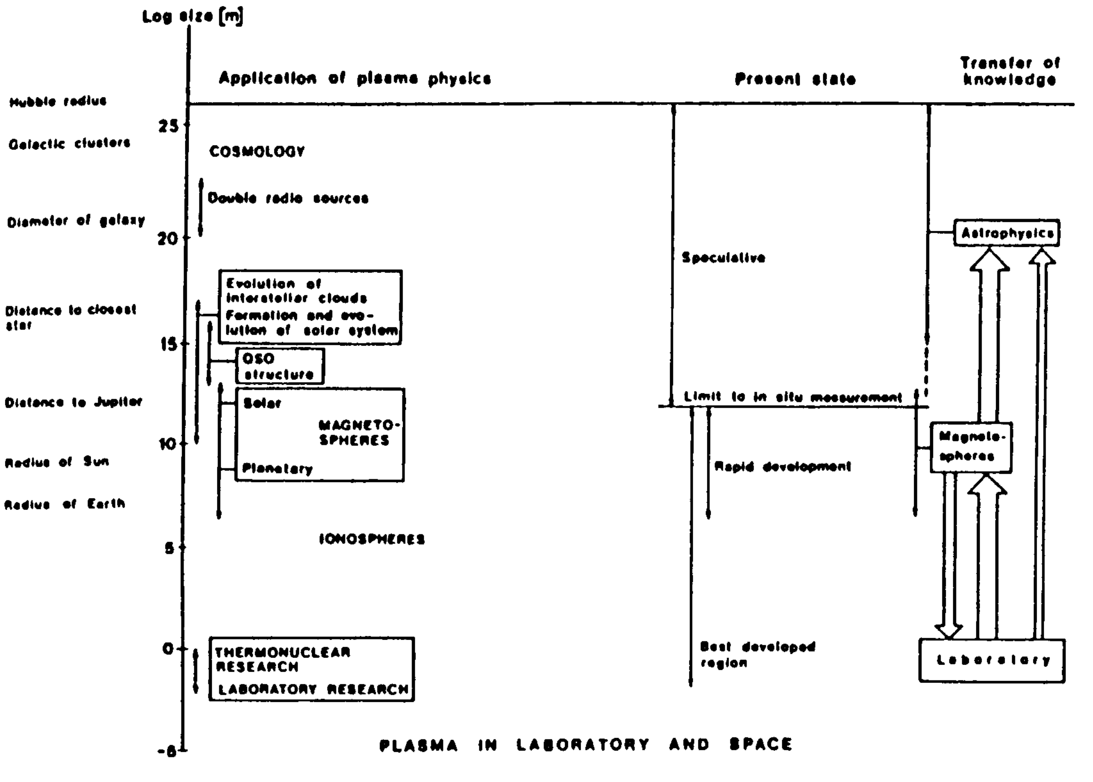

Fig. 1 The diagram indicates regions which can be explored by high quality diagnostics and those which cannot. The transfer of knowledge gained from laboratory experiments to magnetosphere research is now supplemented by a transfer in the opposite direction. Knowledge of more distant regions will also be obtained in this way.

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