Research Proposal

TITLE: Some problems on nonlinear wave propagation in plasmas.

STATEMENT OF THE PROBLEM:

The nonlinear wave phenomena have been studied theoretically in plasma expeditiously since its concept was developed by Washimi and Taniuti (1966) as well as by Sagdeev (1966) and later experimentally (Ikezi, 1973) as well. Thereafter its applications were shown in various plasma environments (Lonngren, 1983; Raadu, 1989). By now, many theoretical observations have shown a very good agreement between the theory and experiments in plasmas as well as with the plasma-acoustic waves observed beyond the earth's surface. The motivation of the investigation for the proposed Ph. D. research problem is appended below:

First of all, the main aim is to develop the nonlinear wave equation from the basic equations governing the plasma dynamics. Based on certain conditions, the wave equation will be solved to investigate the soliton dynamics (Russell, 1838) and relate the observations with those which could be observed in laboratory and space plasmas (Raadu, 1989; Wu *et al.*, 1996). Because of complexity of plasma configurations, the mathematical analysis might not be always desirable to derive the nonlinear wave equation as done by usual method known as reductive perturbation technique or pseudopotential analysis and thus, a new approach is likely to be developed in the Ph. D. research work. The overall studies will attempt to relate with the astrophysical problems observed by the scientific satellites or by other spacecrafts as well as in laboratory plasmas along with the aim of highlighting the formation of nonlinear solitary wave and its salient features as well.

Though the basic development has already been started long ago to study the nonlinear wave dynamics, further literature survey is needed in relation to the astroplasmas and to formulate the problems. The method for deriving the nonlinear wave are though many, but it might be needed to fit further new approaches for finding the nonlinear wave equation and thus to solve for new observations in plasma-acoustic modes in magnetosphere, ionosphere, etc.

From the survey of observations, it has been realised that the usual method for solving the nonlinear wave equation, known as the steady state method, for getting the plasma acoustic wave might not be sufficient and thus it requires to develop alternate approaches. Thus, after the derivation of nonlinear wave equation which has to be developed either by reductive perturbation technique or by pseudopotential method or by other suitable method, new approaches will be carried out too in the ongoing research programme to know the nonlinear coherent structures of solitary waves, e.g., formation and propagation of solitons, double layers, shock-like structures, etc. In the case of the failure of analytical approaches, we will stipulate the numerical procedures to achieve the desired observations.

SURVEY OF LITERATURE:

Many heuristic features of solitons havé been obtained in plasma dynamics through the derivation of a nonlinear wave equation called Korteweg-de Vries(K-dV)

(1895) equation. Actually the process of studying the soliton by K-dV equation started in the sixties after the use of a unique procedure, coined as reductive perturbation technique, by Washimi and Taniuti(1966). In the same decade, a parallel non-perturbative approach has been developed in plasma dynamics by Sagdeev (1966) to derive Sagdeev potential (S-P)equation. Based on these approaches for deriving the nonlinear wave equations, many authors have studied later on the existences of solitons and other nonlinear wave phenomena with a view to having the versatile applications to the experimental observations as well as to space plasma dynamics. During the past several years, the concepts of K-dV and S-P solitons have progressed parallel in the laboratory and space (Raadu, 1989). Though many authors have studied earlier the formation of solitons and their propagation in various plasma configurations, these were limited to simple ideal homogeneous plasma that includes electrons and ions only. However, in general, one should not expect plasma with single ionic species either in laboratory or in space plasmas. That is why, afterwards, much attention was given to the dynamics of multicomponent plasma and has shown a milestone on soliton dynamics. In this regard, theoretical observations revealed that the presence of multiple positive ions will show the schematic variation while the presence of opposite charges, eg. negative ions and multi-temperature electrons expect new findings which were totally absent in two-component plasmas. Das(1975) was probably first to point out the turning era in soliton dynamics showing the compressive and rarefactive solitons caused by the interaction of negative ions. These solitons are furthered in laboratory plasmas and also found in space. These studies were complemented by the works of many authors; among them Tran (1974), Jones *et al.* (1975), Lonngren(1983), Watanabe(1984) are to be quoted further for merit.

However, the theoretical observations so far made are insufficient to acquire the exact knowledge of happenings in plasma-acoustic modes, as the earlier observations were limited to ideal homogeneous plasma. Further, the K-dV solitons in homogeneous medium are quite unable to relate fully with the exact observation in ionosphere, magnetosphere as well as in many astrophysical plasmas in addition to the laboratory plasmas. It should be noted that the observations in inhomogeneous plasmas are lagging behind. The exact K-dV soliton, derived in ideal homogeneous models, are also unable to relate fully with the exact satellite observations carried out in ionosphere, magnetosphere as well as to many astrophysical plasmas. Fewer observations are though made but while solving for the soliton propagation, mathematical manipulations have been made due to which the actual observations, as expected, are missed, and hence fails to relate with the exact observations.

Another versatile area of studying the nonlinear acoustic waves as a fastest growing field is in the dusty plasmas (Goertz, 1989) which are the common plasma configurations in space and astrophysical environments as well as in laboratory plasmas. The ubiquitous nature of the dusty plasmas and its importance in plasma environment has spurred many researchers to study the new features arising in solitary waves (Rao and Varma, 1978).

Many observations on nonlinear wave dynamics have been highlighted in plasma but, still now, because of complex configurations of dusty plasma, the field is yet to be explored expeditiously. Earlier, (Rao and Varma, 1978) concluded by saying that the dust grains in acoustic wave can be treated on the same footing as similar to the multicomponent plasma with heavy negative ions. The theoretical observations in dusty plasma encouraged the experimental observations in dusty plasma (Barkan *et al*, 1995; Verheest, 1996). Further extensions have been made to show the propagation of dust acoustic waves in magnetized plasma too and could be of current growing interest but fewer of them could be solved by proposed method.

Motivation can be regarded to know the formation of the nonlinear wave and its salient features on propagation derived in different configurations of dusty plasmas. The physics of the impact processes and a manner in which dust is produced is yet to be known and its behaviour after which it is produced and the observations might have more importance in many of the space plasma.

OBJECTIVES OF THE PROJECT:

The objectives of the research program involve the following points:

The main aim is to develop the analytical procedure to investigate the nonlinear plasma acoustic waves through the augmentation of various nonlinear wave equations derivable by reductive perturbation technique or by pseudopotential method or by an alternative procedure. Because of an ideal model, the nonlinear wave phenomena might be very complicated for finding the formation of solitons and other nonlinear solitary wave. In such cases, new approaches are desirable to be developed.

In order to study the nonlinear wave, our interest is to derive the Sagdeev potential equation as :

$$\frac{1}{2}\frac{d\phi}{d\xi}+V(\phi,M)=0 \qquad (1)$$

with usual notations or any other equivalent nonlinear wave equation called Korteweg-de Vries equation as :

$$\frac{\partial \phi}{\partial t} + A\frac{\partial \phi}{\partial x} + B\frac{\partial^3 \phi}{\partial x^3} = 0 \qquad (2)$$

which from the basic equations governing the plasma dynamics.

In contrast to the earlier model, our interest is on real plasma model in relation to existing plasma environments to study the nonlinear waves in rotating plasma, multicomponent plasma due to several charges, effect of dust charge grains etc.

DATA AND METHODOLOGY:

Though the wave phenomena is known since the early concept of the plasma dynamics and later on by studying the soliton dynamics, many salient behaviour in relation to space plasmas and its surrounding atmospheres are yet to be known, and needs further extensive investigations. The methods for deriving the nonlinear waves are many and still it might be needed to fit further new approaches for what we are exactly looking forward in this research programme for finding new observations in plasmas related to the environments of magnetosphere, ionosphere as well as lithosphere, etc. Further, computational plasma dynamics is likely to be one of the thrust areas planned in the work. Motto is to study the general wave phenomena with a view to showing the transition in natural plasmas as well as in plasmas contaminated with the dust charge grains.

ORGANISATION:

Based on the above mentioned view, our motivation will be the problems in plasmas which will be formulated from the following plasma configuration as appended below:

(i) Nonlinear waves in multicomponent plasmas with a view to knowing the salient features of soliton formation and its propagation in plasma.

(ii) Because of having the rotational effect in every physical context related in space, our interest is to study the interaction of slow rotation in the dynamics of nonlinear acoustic mode in plasma.

(iii) Further, observations are likely to be extended in plasma model with the consideration of magnetic field. But it is the utmost desire to yield soliton dynamics and other different features of plasma-acoustic waves.

(iv) The work will be furthered to plasma contaminated with dust grains known as dusty plasma, which could be found as common occurrence in laboratory and space plasmas. The usual method as discussed earlier will be employed to execute the nonlinear dust-acoustic wave and its characteristic features in the dynamical system.