Received: May '22
Revised:
Accepted: Jun '22

A RESEARCH ON THE CONTRIBUTION OF MHD PULSES, WAVES AND INSTABILITY IN TRIGGERING NUMEROUS SOLAR TRANSIENTS AT DIVERSE SPATIO-TEMPORAL SCALES

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ABSTRACT

We provide a three-dimensional compressible magneto hydrodynamic (MHD) simulation in spherical coordinates for MHD wave propagation in a structured solar environment. A magnetic field profile with an open pole and closed equator is used. Initial solar atmosphere consists of the chromosphere and corona, approximating the photosphere transition area. This study examines MHD wave propagation in a two-layer solar atmosphere. Thus, $r = 1\ R_s$ is added to the chromosphere. We compare this instance to one where the pulse is introduced at the corona's base ($r = 1.018\ R_s$). Where the disturbance begins in the chromosphere, a pair of fast mode waves and a slow mode MHD wave is formed. (2) If the disturbance is launched at the bottom of the corona ($r = 1.018\ R_s$), we observed a pair of fast and slow mode MHD waves travelling upward to the corona and another pair propagating downhill toward the photosphere. We argue that the model can reveal the relationship between flare initiations more ton waves of the chromosphere and Extreme Ultraviolet Imaging Telescope waves in the low corona.

Keywords: Solar Atmosphere, MHD Pulses, Chromosphere, Coronal Disturbance.

1. INTRODUCTION

Along with the naturally observable or massive progressions of the plasma, MHD waves also comprise perturbations of the electric field and electric flow. To put it simply, the solidified-in condition of the plasma is responsible for the MHD dormancy that is associated with the proximity of MHD waves and the MHD re-establishing capabilities associated with the attractive strain and aggregation (gas in addition to attractive) pressure (opposite movements of the plasma lead to the difference in the attractive field geometry, and the a different way). The existence of MHD waves in Earth's magnetosphere has been seriously considered for a very long time. Recently, beginning in the late 1990s, with the first impressions of these waves with high-goals EUV imagers on the satellite missions SOHO and TRACE, there has been a resurgence of interest in MHD waves in the solar crown.

As previously mentioned, the finding of the magnetic field in the solar corona served as the initial spark for this interest in MHD waves. Observations from the corona and magnetospheres give us a plethora of data on MHD waves. Numerous hypothetical models are provided in both of these contexts that are consistent with expressing characteristics of MHD waves as they are observed in the real world. In light of the intensive investigation of MHD waves, multiple comprehensive evaluations and surveys have been published on its many facets. You can look for these studies on the 'Net. Unfortunately, MHD wave phenomena in the solar corona and the Earth's magnetosphere are typically studied in isolation from one another. Also, the employment of different terminology and different observing methodologies complicates cross-talk between these two networks, which are focusing on very similar plasma conditions. Insight into the physical miracles associated with MHD waves in the crown and magnetosphere gives us reason to be optimistic about expanding our understanding of MHD waves generally. Both of these exploration networks gathered up complementary information, and they made improper use of contrast and comparison.

The presence of MHD wave cities in the crown and magnetosphere has the potential to further studies in these fields, and is also relevant to other astrophysical, geophysical, space, and laboratory plasma contexts. This research was conducted to pave the way for future collaborations between the research networks studying MHD wave concerns in the solar crown and the magnetosphere of Earth. However, in an effort to lay the platform for the ensuing debate, we will briefly go over the most essential features of the plasmas present in the corona and the magnetospheres. The next section will focus on demonstrating the validity of a hypothetical proposition and discussing explicit phenomenology. Finally, we provide a graphical representation of the correlations and discordances between the various MHD waves that have been seen. Remote sensing allows for an approximation of solar crown wave activity, with only global wave characteristics being determinable. However, with magnetosphere waves, there is no access to point-by-point spatial data, and in-situ parameters can only be approximations.

Ultra-low recurrence (ULF) waves in the recurrence band at frequencies between a few hertz and a few millihertz can be used to study MHD wave patterns in the terrestrial magnetosphere. However, despite the vast differences in scale, the frequencies of the MHD wave patterns recorded in the solar crown all cluster in the same region. Hypothetical models are presented alongside an analysis of observational data acquired from the ground and satellites. The goal of our work has been to provide both observational and hypothetical ideas obtained from magnetospheres material science that may be employed in solar material science, and vice versa. We have not just conducted independent surveys of ULF waves in the magnetosphere and solar coronal waves. We also present ambiguous instances where the overall MHD wave network's knowledge and experience can be applied. Although the primary audience for this survey is graduate students in magnetosphere material science and solar physical science, it is curious about topics of interest in related disciplines as well. In the end, the solar section is intended for solar experts, while the magnetosphere section is prepared for physicists who specialise in that field. The length of the reference list would make the audit run over its permitted time.

1.1. Theory of magneto hydrodynamic waves

We use the instrument of magneto hydrodynamics to concentrate on the elements of plasma under these circumstances in light of the fact that the air of the sun is loaded up with countless attractive circles that associate with each other. There are various outcomes that the coronal attractive field has on the hydrodynamics of the plasma. The attractive field can assume a functioning part in specific circumstances (where the attractive calculation changes), including the effort of a Lorentz force on the plasma, the gathering and stockpiling of non-likely energy, the setting off of an unsteadiness, the changing of the geography (by different sorts of attractive reconnection), and the speed increase of plasma structures (fibers, prominences, coronal mass Ejections (CMEs)). These peculiarities require the apparatuses of magneto hydrodynamics for us to fathom and measure them. The investigation of magneto hydrodynamic cycles in the sun oriented crown are especially exceptional on the grounds that it addresses the main lab of astrophysical plasmas where we can spatially determine the designs of revenue from one viewpoint, while likewise showing more remarkable plasma processes than can be made in any earthbound research center then again. This makes the investigation of these cycles in the sun based crown especially fascinating. Magneto hydrodynamics, or MHD for short, is a liquid hypothesis that is expressed as far as plasma properties like thickness, tension, temperature, and stream speed.

As indicated by the Maxwell conditions, the plasma shows a reaction to the electric and attractive powers following up on it at a naturally visible scale. The field of magneto hydrodynamics makes use of the equations of Maxwell in conjunction with equations of continuity, equation of state, equation of motion, and energy equation.

1.2. Solar interior

The primary criteria used to categorise the solar interior into its three primary areas are the mechanisms that generate and transmit energy. They are the centre, the radiating, and the periphery. The solar core, which extends outward to cover between 20 and 25 percent of the solar radius, is the part of the planet where thermonuclear reactions produce the majority of the sun's energy the transformation of hydrogen into helium via fusion. The fusion processes that are taking place inside The Sun are mostly composed of a chain reaction known as p–p (proton–proton). Nevertheless, CNO Only about 0.8% of carbon is produced through the (carbon–nitrogen–oxygen) chain reactions. The temperature of the solar core is approximately 1.6 x 107 K. With a density of approximately 1.6 x 105 kilogrammes per cubic metre 99% of the sun's energy comes from its centre. Despite having only half the mass of the sun and one-fiftieth of its volume, it has one-fiftieth of its energy proportionally to the entire volume.

Radiation and conduction are the two modes that are responsible for transporting the high energy that is produced in the core to the radioactive zone. The zone of radioactive activity is extended to approximately 70 percent of the solar radius from the edge of the core. In this region, the high-energy gamma-ray photons that are emitted by the core are subjected to massive collisions, which result in their transformation into photons that can be seen. Before they get to the surface of the water. In the space between the radioactive and the overlaying elements convective zone, there is a somewhat thin boundary that is referred to as the tachocline. It possesses a thickness of approximately 0.09 0.04 solar radii.

It is important to bring this out that inside the sun; the radioactive interior revolves almost like a hard cylinder differential rotation occurs between the body and the convective zone. In the form of tachocline , not only does it create a substantial shear because of the fact that it separates these two zones, but it also difference in rotation speeds, and it is believed that this is the site where the location of the solar dynamo is.

1.3. Waves in the solar atmosphere

The Sun and Heliospheric Observatory (SOHO) and the Change Locale and Coronal Wayfarer (Follow) shuttle were liable for the principal fruitful endeavours to notice wave movement in the sun powered air after their separate send-offs.

They were able to detect a variety of wave modes, including compressible waves in polar plumes and fan loops, longitudinal standing oscillations in coronal loops, flare-generated kink oscillations, and others. The different waves that exist in the solar atmosphere can be identified by examining the consequences, such as modulations in intensity and density, which manifest themselves in the plasma as a direct result of the waves' ability to propagate. For instance, the movement of compressional waves causes a change in density, which in turn results in a shift in the brightness (or intensity) of the waves. There have also been reports of variations in the velocity measured along the line of sight (LOS) when there was a component that was directed toward the observer. The propagation of intensity oscillations along a fan loop is depicted as ridges of dark and brilliant colour in Figure 1.7. They are also sometimes referred to as intensity disturbances that propagate (PIDs). In contrast, incompressible Alfven waves do not exhibit any oscillations in their radiative properties. While moving in a direction perpendicular to the observer, these transverse waves produce phenomena known as line-of-sight (LOS). Coronal seismology has developed from a theoretical framework into a more advanced and applicable science as a result of the observations of a variety of wave modes in resolved coronal structures.

Important theoretical constraints are provided for the modelling of the solar environment by the physical plasma parameters inferred from seismology. These parameters include the magnetic field, temperature, density, transport coefficients, and scale heights, among others.

Withbroe (1983) used data from the Harvard Skylab experiment to observe compressible disturbances for the first time in polar plumes. He did this by analysing the Mg X 625 a line emission. After that, Ofman et al. (1997) used the white light channel of SOHO/UVCS to find that coronal holes experience density oscillations with periods of approximately 9 minutes. By employing EIT/SOHO measurements, Deforest and Gurman (1998) discovered intensity disturbances in polar plumes that had propagation speed of between 75 and 150 kilometres per second, a periodicity of between 10 and 15 minutes, and intensity changes of between 10 and 20 percent. Berghmans and Clette (1999) were the first researchers to notice the presence of propagating intensity disturbances (PIDs) in coronal fan loops.

Later on, De Moortel et al. (2000) were able to confirm their presence in the observations that were taken by Transition Region and Coronal Explorer [TRACE] in the 171 A channel. Following the publication of these preliminary results, a number of investigations have been carried out in an effort to get an understanding of the PIDs present in various coronal structures, including fan loops, plumes, and interplumes. All of these experiments demonstrated that the apparent phase speeds of the PIDs are slower than the acoustic speed in the corona; hence, the slow magneto acoustic waves label was applied to them. The PIDs that are seen in the solar corona's fan loops are generally thought to be caused by the leaking of pmode oscillations that travel along the magnetic field lines. This is the general consensus among researchers. It has also been noted that these intensity waves that are propagating undergo damping. During their research in 2010, Gupta and colleagues (2010) found that the phase speeds of PIDs increased from a value of 130 14 km s1 immediately above the limb to a value of 330 140 km s1 at a height of around 160 arc sec. Based on their observations of waves travelling at a high phase speed in the inter-plume areas, the researchers concluded that the waves are most likely either Alfv'enic or fast magneto-acoustic.

1.4. Solar atmosphere waves

The photosphere's Doppler grams revealed the first reports of oscillatory motions on the Sun (Leighton et al., 1962). It was discovered that the velocity field exhibits a quasi-sinusoidal variation at a specific place with amplitude of about 100 ms and a period of about 5 minutes. In studies, research has been focused on shallow near-photosphere layers and has focused on wave creation, damping, and trapping. The 5-minute oscillations that were seen were then understood to be the standing acoustic waves trapped in cavities extending deeply into the interior Deubner's observational verification (1975). The distribution of power in the Deubner's (1975) "k" plane fell along well defined, narrow ridges whose Shape and position were consistent with the theoretical rich mode structure the theory of trapped acoustic waves being calculated. A spectrum of acoustic (p mode, pressure), or gravitational waves will result from a disruption of the hydrostatically maintained plasma in the solar interior basic (*f* mode, surface gravity) waves or (*g* mode) waves, with the depending on the location in the Sun and the frequency of the perturbations, dominant restorative force The 5-minute oscillations that have been seen are the acoustic, *p* mode reversals. These oscillations' dynamics are controlled by the alterations in the Sun's internal sound speed. These *p*'s amplitudes are *p*. At the solar surface, there are hundreds of kilometres worth of modes. This fluctuation can be found using sensitive spectral line intensity or Doppler imaging *G* modes, or density waves with gravity (negative buoyancy), are used in imaging as their restoring force (of displaced material). They are kept inside observations of the Sun below the convective zone are essentially impossible at the surface. As they pass through the convection zone, these g modes vanish are believed to only have millimetre-sized residual amplitudes at the photosphere. There have been numerous reports of g mode observations, although they were not totally verified. *f* modes, which are gravity waves as well, happen at or near where the temperature gradient once more falls below the Arithmetic value.

1.5. Solar Atmosphere Heating

The heating problem with the solar atmosphere has perplexed solar physicists. Over the years, many different types of heating systems have been invented, and they can generally be categorised as either magnetic or nonmagnetic. The non-magnetic heating hypothesis states that acoustic waves generate heat, which then evolves into shock waves with large pressure and density gradients in the atmosphere. Other names for this process include the hydrodynamic or field-free mechanism. Furthermore, the magnetic heating mechanism can be broken down into alternating current (ac) and direct current (dc) heating. Joule heating and magnetic reconnection are two methods for converting magnetic energy into mechanical motion, both of which are employed in direct or dc magnetic heating. When heated indirectly or with alternating current, the magnetic field lines catalyse the process without being affected. When using dc heating, the foot points of the magnetic fields are continuously shuffled using the random walk-like features of the photospheric granular and super granular flows.

Due to the high electrical conductivity of the solar environment, magnetic field lines are also encased in plasma. Current sheets form when magnetic field lines twist and wrap around one another in regions of extreme tension. Once the current in these sheets reaches a critical value, reconnection takes place, releasing the magnetic energy and possibly heating the solar environment. In ac heating models, energy is generated from the sun's dispersion of waves. Because the speed of magneto acoustic waves is a function of both the direction of propagation and the plasma properties, they are reflected off the transition region, where the pressure and density are drastically different. So, these waves can't carry power from the photosphere to the corona. At that time, heating with Alfven waves would make the most sense. Alfven waves last far longer and vanish from the corona for only a short time. So it's hard to turn wave energy into heat.

2. FUNDAMENTAL EQUATIONS AND THE INITIAL STATE

Three-layered, time-reliant, ideal (non-dissipative), MHD conditions make up the principal conditions. We utilize an adiabatic energy process with a polytrophic list (*g*) of 1.67 to surmise the energy condition. Mass, force, energy preservation, and attractive enlistment are among different conditions. The nonlinear cooperation between the plasma stream and attractive fields is considered by the concurrent arrangement of these situations.

2.1. Initial Atmosphere

This study aims to look at various elements of how the organised two-layer solar environment (chromosphere, transition zone, and lower corona) affects the global propagation of MHD waves. Future research of propagating shock waves must start with such a study as a vital prerequisite. Subsequently, the underlying attractive field was decided to be a clear, genuinely significant model of a dipole expected attractive field, which has the basic mathematical property of the spreading of the attractive field with level. This starting field's analytical formulation in spherical coordinates (r, Θ,φ) is given by:

$$B_{or}(r,\theta) = \frac{B_o^* R_s^3 \cos\theta}{r^3}, \quad B_{o\theta}(r,\theta) = \frac{B_o^* R_s^3 \sin\theta}{2r^3}, \quad B_{o\varphi} = 0$$

2.2. Boundary Conditions and Distribution of the Numerical Grid

The limit conditions Wu et al. (2001) gave are the very ones that were utilized for this calculation. Time-subordinate trademark limit conditions are utilized to decide the lower and upper limit conditions in the spiral bearing. Since all actual amounts should be refreshed from each time step, the similarity conditions that are acquired from the administering conditions should be utilized [Wu and Wang, 1987]. As per the course of highlights in the outspread bearing, the non-reflecting circumstances are applied. Plausible disregarding these elements will prompt made up conditions (Wu et al., 1996a). The longitudinal (j) and scope (q) bearings utilize intermittent limits. We won't rehash the exact numerical recipes used for the spiral limit conditions since they are given in Wu et al. [2001]'s. Stretching out the upper spiral limit to any area in interplanetary space is conceivable.

3. RESULTS

By entering the attractive field (equation 1) into the arrangement of MHD conditions, we had the option to mimic the scientific portrayal of an underlying climate in static balance. This trial demonstrated that the early environment is, truth is told, in a condition of static harmony. To accomplish appropriate mathematical goal to uncover the legitimate actual course of the MHD waves spread through the two layer sunlight based air. These two zones depend on the environmental construction found in Figure 1; explicitly, the change area is 1 R_s r 1.018 R_s since the foundation of the crown is at r = 1.018 R_s and the lower part of the chromosphere is at r = 1 R_s. With various heartbeat qualities (i.e., [p - po (R_s)]/p_o (R_s) = 0.5, 1, 3, 4) and beginning plasma betas (i.e., 0.2 and 2.0), we have run various re-enactments to develop the unsettling influence at better places. The equator, centre scope, and shafts are these areas. Because of the aggravation's ability to deliver anisotropic wave proliferation qualities, the idea of the actual cycles uncovers that the outcomes for unsettling influence areas around center scope are the most charming.

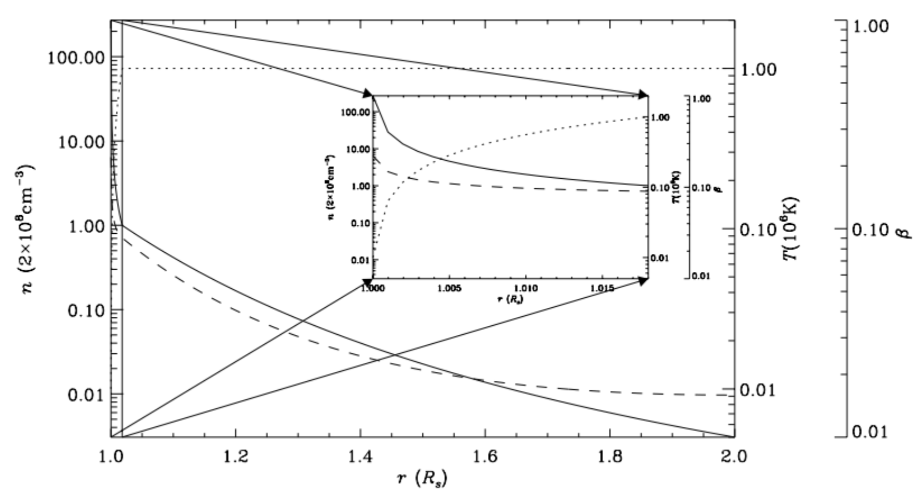

Figure 1: Electronic number thickness n (strong), temperature T (specked), and plasma b (ran) at Θ = 66 from the shaft. The subplot shows the above amounts in chromosphere and progress zone

Because of this, two reproduction circumstances with Θ = 66 degree at center scope have been picked. Moreover, we chose plasma beta, β = 0.2 and a particular heartbeat strength of four for the show. It's a given that we wish to check out at a few central effects of anisotropic wave engendering across the two-layer climate. It follows that we should find these two models in the accompanying way: To start with, the unsettling influence is situated at the chromosphere (r = 1 R_s), and second, it is situated at the foundation of the crown (r = 1.018R_s).

3.1 Chromospheric Disruption

In this scenario, we start a pressure pulse $\frac{p-p_o(r)}{p_o(r)} = 4$ p_0 (r) at r = 1 R_s, Θ = 66 degree, and φ = 180 degree in an area of 18 degree x 18 degree. This pulse is 2.8 x 10^{26} ergs. We don't explore how this energy is input physically. This pressure pulse lasts ~500 s (0.34 $_{tA}$), and its amplitude peaks at 0.25 $_{tA}$. The pulse is kept at 0.34 $_{tA}$. Pulse stops at 0.34 tA.

Quick method of MHD wave (F), slow method of MHD wave (S), driving edge of mass movement (M), and initiated quick method of MHD waves (F1) when irritation is turned off. The rings demonstrate one and two sun oriented radii. Figure 4 shows a meridian cut of the thickness improvement shapes through the beat's middle meridian to assist with imagining these examples. Figure 4's scale isn't uniform in light of the fact that the progress zone was augmented to show MHD wave designs. Figure 3 shows a hill formed thickness improvement at t = 0.05 tA after the strain unsettling influence. Mass movement and pressure MHD wave fronts couldn't be settled. At t = 0.3 tA, the quick mode MHD wave has spread to the lower crown. At t = 0.7 tA, it arrived at the upper boundary and nearly left the computational space, trailed by a rarefaction zone.

At 1.35 tA, the initiated quick mode and slow mode MHD waves are displayed, trailed by cylinder like mass movement.

The advancement of relative thickness variety (Dr) all through the spiral distance at scope Θ = 66 and longitude φ = 177. F and S are a quick/slow sets of waves followed by F1 when the beat is turned down at the chromosphere. At t = 0.7 tA, the adjusted unsettling influence arrives at r 1.05 Rs. No straight wave coupling strategy has anticipated this intricate way of behaving

3.2 Coronal Eruption

This time, we've begun a tension heartbeat that is indistinguishable from the one in example 1, yet this time it's begun at the foundation of the crown (r = 1.018 R_s), mid scope (Θ = 66), and longitude (φ = 180) — a decision that was made indiscriminately however is fundamental since it's a similar spot as case 1. Obviously the focal point of the organized sunlight based climate is where this aggravation is found, subsequently when the beat is radiated, both vertical and descending spread of the MHD waves will start away from the unsettling influence's source.

Specifically, a couple of quick and slow mode waves goes to the crown while a subsequent pair goes through the chromosphere. Figure 2 shows the locations of these wave fronts' corresponding apexes. Figure 2's characteristic resembles a recent chromosperic wave observation made by Gilbert and Holzer (2004) rather well. Figure 2 illustrates how fast/slow waves spread far more quickly in the corona than in the chromosphere, while Gilbert and Holzer's measurement from 2004 demonstrates that the corona's solid fast wave front extends far beyond that of the chromosphere.

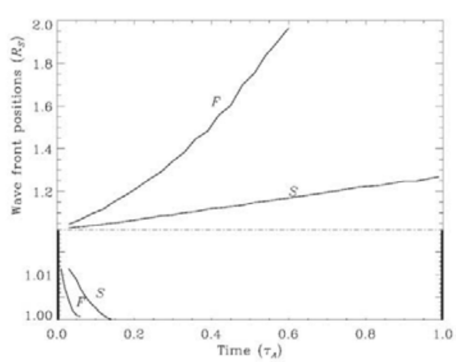

Figure 2: Coronal wave front locations (r = 1.018 Rs). F and S denote fast and slow waves. The vertical axis shows distances (R/ Rs) from calculation grids, and the horizontal axis represents Alfven time (t_A).

Figures 3 and 4 portray the reaction of thickness, speed, and attractive energy in the progress region as a component of spiral distance (underneath r = 1.018 R_s) at different focuses following the presentation of the tension heartbeat aggravation. With the presentation of the aggravation, two sets of MHD quick and slow waves are framed, and by analysing these discoveries, the varieties brought about by the place of the unsettling influence (i.e., argument 1 against the current case 2) can be perceived immediately. Another pair spreads descending toward the photosphere, while the main pair spreads up into the crown. Results demonstrate that in the crown, the quick and slow mode waves spread with a typical speed of 703 km s1 and 177 km s1, separately. 140 km s1 and 47 km s1 are the other quick and slow mode waves that are plunging into the chromosphere, individually. The quick and slow mode MHD waves that are engendering vertically after the beat has halted are extension waves since they are traveling through a climate where the thickness is falling quickly.

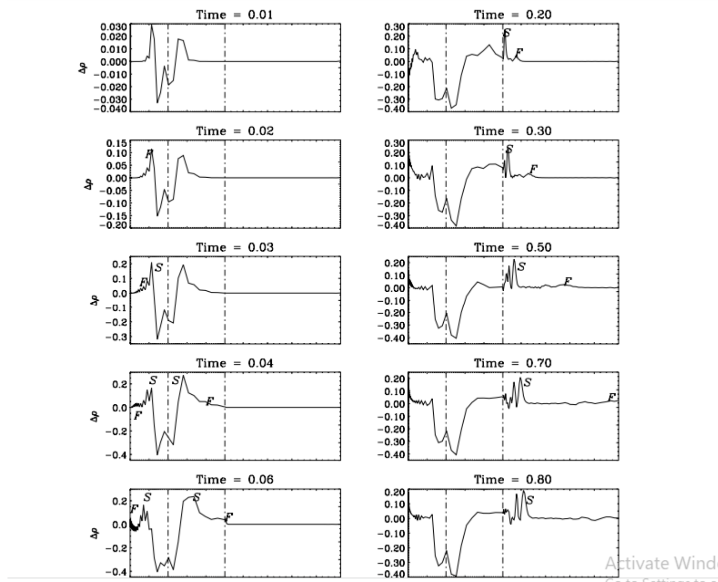

Figure 3: Coronal disturbance radial profiles of relative density increment Dr= 0.04 at latitude ϴ =66 in meridian and longitude φ =177

It is guessed that this pair will speed up and that a quick mode MHD shock will frame. The mathematical relic in Figure 4's vr motions behind F and S. Comparable attractive energy motions. The internal spread pair, then again, shows an easing back when the waves enter an environment with an almost dramatically rising thickness.

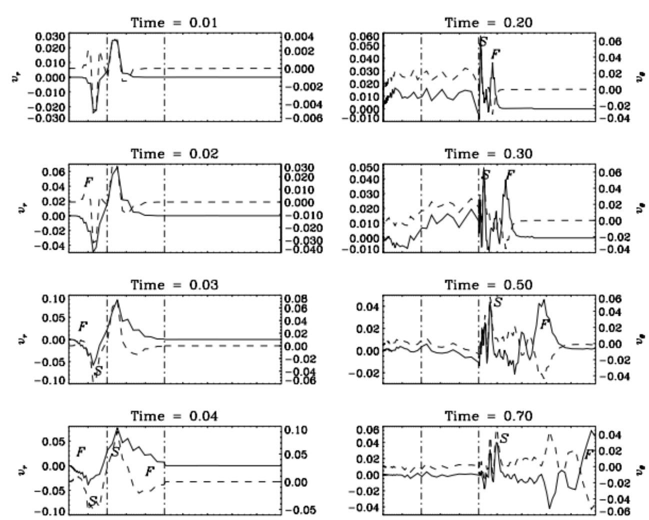

Figure 4: Coronal disturbance vr (solid line) and vq (dashed line) radial profiles at latitude 66 in meridian and longitude 177.

4. CONCLUSION

As part of this study, we modelled how MHD waves propagate through the transition region from the chromosphere to the lower corona. Through this speedy investigation, a number of surprising findings surfaced. The pressure pulse-induced plasma flow interacts with the original magnetic field, which is only two-dimensional in the meridional plane. The interaction gives rise to the third component velocities and magnetic fields (B and v). One of the main differences between two- and three-dimensional magneto hydrodynamics is this. Both fast and slow magneto hydrodynamic waves are generated when the photosphere is perturbed (r = 1 Rs). Two sets of fast and slow magneto hydrodynamic waves are generated when the disturbance is close to the corona's base (r = 1.018 Rs), with one set travelling downward to the chromosphere and the other set travelling upward and out into the corona (Figures 2 and 3). The amplitude of the wave was found to be related to the pulse's strength (not shown for space). Although the strength of a magnetic field is proportional to the speed of a wave in plasma, the beta of the plasma acts in the opposite direction. For weak pressure pulses (Dp/p0 = 0.5), our simulation results agree (but are not shown to) with planar linear analysis. Finally, we examined the propagation of MHD waves from the chromosphere to the corona by running a three-dimensional MHD simulation. The reliability of this model can be tested against the data. Moreton waves [Moreton, 1960] and EIT waves [Thompson et al., 1999, 2000] in the low corona, and the majority of observed coronal chromosphere waves [Gilbert and Holzer, 2004], can be linked using the model. In the lower corona, see [Moreton, 1960] and [Thompson et al., 1999, 2000]. This probe will continue in the future.

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