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Dual spacecraft observations of a compression event within the Jovian magnetosphere: Signatures of externally triggered supercorotation?

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[1] By using Cassini as an upstream solar wind monitor, we are able to infer increases in the interplanetary dynamic pressure upstream of Jupiter as the spacecraft approached the planet. Observations are made of the effect that these pressure increases had upon both the fields and particles within the Jovian magnetosphere as measured by the Galileo orbiter, which had subsequently reentered the magnetosphere on the duskside. As the external pressure increased, so too did the total field magnitude at Galileo (in particular the Bz and Bφ components). In addition, strongly leading field angles were observed following the onset of the compression and strongly lagging fields during reexpansion. These observations are consistent with the concept of external control of the angular velocity of the magnetospheric plasma due to conservation of angular momentum within the system. Heating of the plasma can be seen as a pronounced increase in particle flux as measured by the Energetic Particles Detector (EPD) instrument aboard Galileo. Changes in plasma velocity inferred from energetic particle anisotropies at Galileo appear to be consistent with the behavior of the changing magnetic field angle. The overall behavior and response time of the system appears to be consistent with recently published theoretical modeling of the Jovian magnetosphere-ionosphere coupling system. *INDEX TERMS:* 2756 Magnetospheric Physics: Planetary magnetospheres (5443, 5737, 6030); 6225 Planetology: Solar System Objects: Mars; 2784 Magnetospheric Physics: Solar wind/magnetosphere interactions; 2764 Magnetospheric Physics: Plasma sheet; 2760 Magnetospheric Physics: Plasma convection; *KEYWORDS:* magnetospheric compression, Jovian magnetosphere, magnetosphere-ionosphere coupling, solar wind, Cassini

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1. Introduction

[2] The 2001 Cassini flyby of Jupiter offered for the first time an opportunity to study a magnetosphere other than the Earth's using dual point spacecraft observations. The trajectory of Cassini took it within the magnetosphere proper only for a brief period, the spacecraft spending most of the flyby either in the solar wind or the magnetosheath. This brief encounter allowed interesting dual spacecraft results to be obtained regarding the transient response of the magnetopause structure to external pressure [*Kurth et al.*, 2002].

[3] For most of the Jupiter approach phase (as Cassini's heliospheric longitude approached to within a few tens of degrees of that of the planet), Galileo was located in the solar wind on the duskside of the magnetosphere. The spacecraft was therefore unable to make in situ measurements of the system that could be correlated with the prevailing solar wind parameters. However, between days 343 and 348 in the year 2000, Galileo encountered the Jovian magnetosheath on multiple occasions before eventually entering the magnetosphere, where it remained until Cassini itself crossed the bow shock.

[4] Numerous transient solar wind events including Interplanetary Coronal Mass Ejections (ICMEs) were observed by the Cassini magnetometer on its approach to Jupiter [*Hanlon et al.*, 2004]. Two of these events have been discussed previously regarding an increase in the hectometric radio emissions from the planet [*Gurnett et al.*, 2002]. The response of the Jovian system to the changes in external pressure that would accompany such events has been examined previously [*Southwood and Kivelson*, 2001; *Cowley and Bunce*, 2001, 2003a, 2003b] with particular reference to the magnetosphere-ionosphere coupling system. Results of this theoretical work suggest that increases or decreases in external pressure would cause transient changes in the angular velocity of the Jovian plasma, and

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hence the frozen-in magnetic field structure, before settling to a new equilibrium state on a timescale of a few tens of hours. Here we will examine data taken by Galileo within the Jovian magnetosphere as an interplanetary shock wave (almost certainly not related to an ICME), passed over the system compressing it from a very extended state.

2. Observations

[5] On day 354 of the year 2000, Cassini observed an interplanetary shock event whilst the Galileo orbiter was within the Jovian magnetosphere at approximately 85 R_J and 1950 MLT, 10 days after it had reentered the magnetosphere via the dusk flank. At this time Cassini was approximately 171 R_J upstream of Jupiter, at an angle of 18 degrees to the Jupiter-Sun line. This period has previously been investigated by *Krupp et al.* [2002], who studied the leakage of Jovian particles into the solar wind.

[6] Figure 1 shows the trajectories of both spacecraft in a coordinate system in which the *z* axis is centered upon the Jovian geographic spin axis, while *x* points in the direction toward local noon, and *y* completes a right-handed set. Cassini's trajectory is marked on the plot by the dot-dashed line and Galileo's with a dashed line. A section of both of the trajectories has been marked with a solid line. This denotes the time period at both spacecraft that will be discussed below. Two model magnetopause shapes [*Joy et al.*, 2002] have been plotted for reference, one for a low expected dynamic pressure (0.01 nPa) and one for high (0.5 nPa). As can be seen, Galileo is expected to stay well within the magnetosphere during this period, even for compressions at the more extreme end of the scale.

[7] Figure 2 shows a time series plot of the period in question. Figure 2a shows the solar wind magnetic field magnitude as measured by the Cassini Dual Technique Magnetometer (MAG) instrument [*Dougherty et al.*, 2004] as the spacecraft moved toward the planet. As can be seen, the solar wind field remained at a steady 0.2–0.8 nT until 1511 UT on day of year (DOY) 354, at which time a sharp increase in the field magnitude was observed, indicative of an interplanetary shock wave passing over the spacecraft. The onset of this event has been marked in the panel with a vertical line. The data gaps in this plot are due to downlink restrictions that were imposed upon the spacecraft as a whole by maintenance procedures. This was due to friction problems arising within one of the reaction wheels carried aboard.

[8] Figure 2b shows the dynamic pressure at Cassini as predicted by a one-dimensional magnetohydrodynamic (MHD) model, in which solar wind data taken at the Earth (which was within 20 degrees of Jupiter in heliospheric longitude) has been propagated out to the orbit of the spacecraft. The data used to perform this simulation were taken from the MAG [*Smith et al.*, 1998] and Solar Wind Electron Proton Alpha Monitor (SWEPAM) [*McComas et al.*, 1998] instruments aboard the ACE spacecraft [*Stone et al.*, 1998]. The propagation data were produced using the Versatile Advection Code (VAC) [*Tóth*, 1996]. As can be seen, the model predicts a sharp increase in pressure to accompany the observed magnetic field enhancement, although it arrives approximately 1 day too late (halfway through day 355). A more complete comparison between the Cassini data and this MHD model is contained within the companion paper [*Hanlon et al.*, 2004]. However, for our purposes here we will note that the MHD model does indeed predict a substantial increase in the solar wind dynamic pressure and that the error in the shock arrival time is on the order of 5% of the overall transit time from 1 AU.

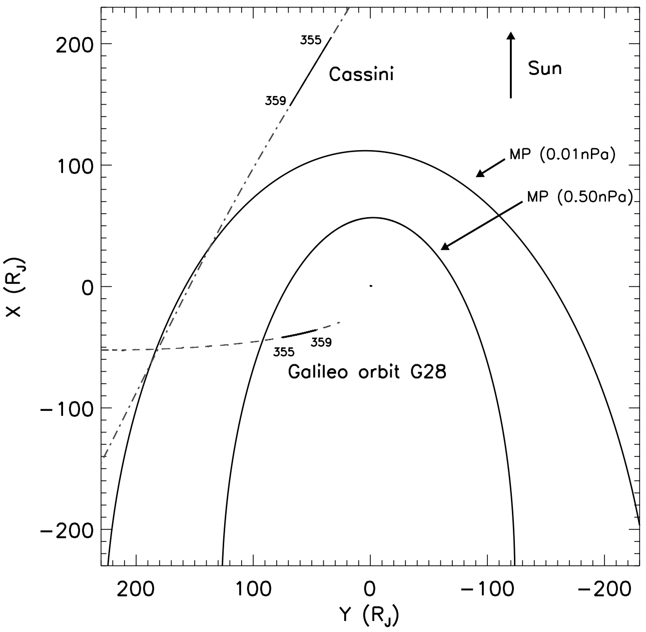

Figure 1. A schematic diagram of the Galileo and Cassini trajectories during the Cassini fly-by of Jupiter. The *z* axis of the coordinate system employed is centered on the Jovian geographic spin axis, while *x* points in the direction toward local noon, and *y* completes a right-handed set. Two model magnetopause shapes have been plotted, one for a high (0.5 nPa) dynamic pressure and one for low (0.01 nPa) [*Joy et al.*, 2002]. Galileo's trajectory is marked by the dashed line and Cassini's is marked by the dot-dashed trace. A portion of each trajectory has been marked solid; this represents the time period DOY 355–359.

[9] Figures 2c, 2d, and 2e show the $B\rho$, $B\varphi$, and Bz components, respectively, of the magnetic field at Jupiter as measured by the MAG instrument [*Kivelson et al.*, 1992] aboard the Galileo orbiter. The field is plotted in a cylindrical polar coordinate system in which the *z* axis is aligned along the magnetic dipole axis of the planet. Figure 2f shows the field magnitude. Vertical lines have been drawn onto these and all remaining panels, one at approximately 5 hours after the onset of the shock wave within the solar wind and one at approximately 1900 UT on day 358. It is clear that the section of data defined in the plot between these two vertical lines encompasses a period in which the Bz and $B\varphi$ components of the magnetic field, although varying, are raised in overall magnitude. This increase in field magnitude combined with observations that will be outlined below, we will argue, is a direct observation of a compression of the Jovian magnetosphere, this compression being caused by an increase in the solar wind dynamic pressure due to the event observed 5 hours previously by Cassini. We note that the observed increase in the magnitude of Bz at Galileo is approximately 3 nT, having

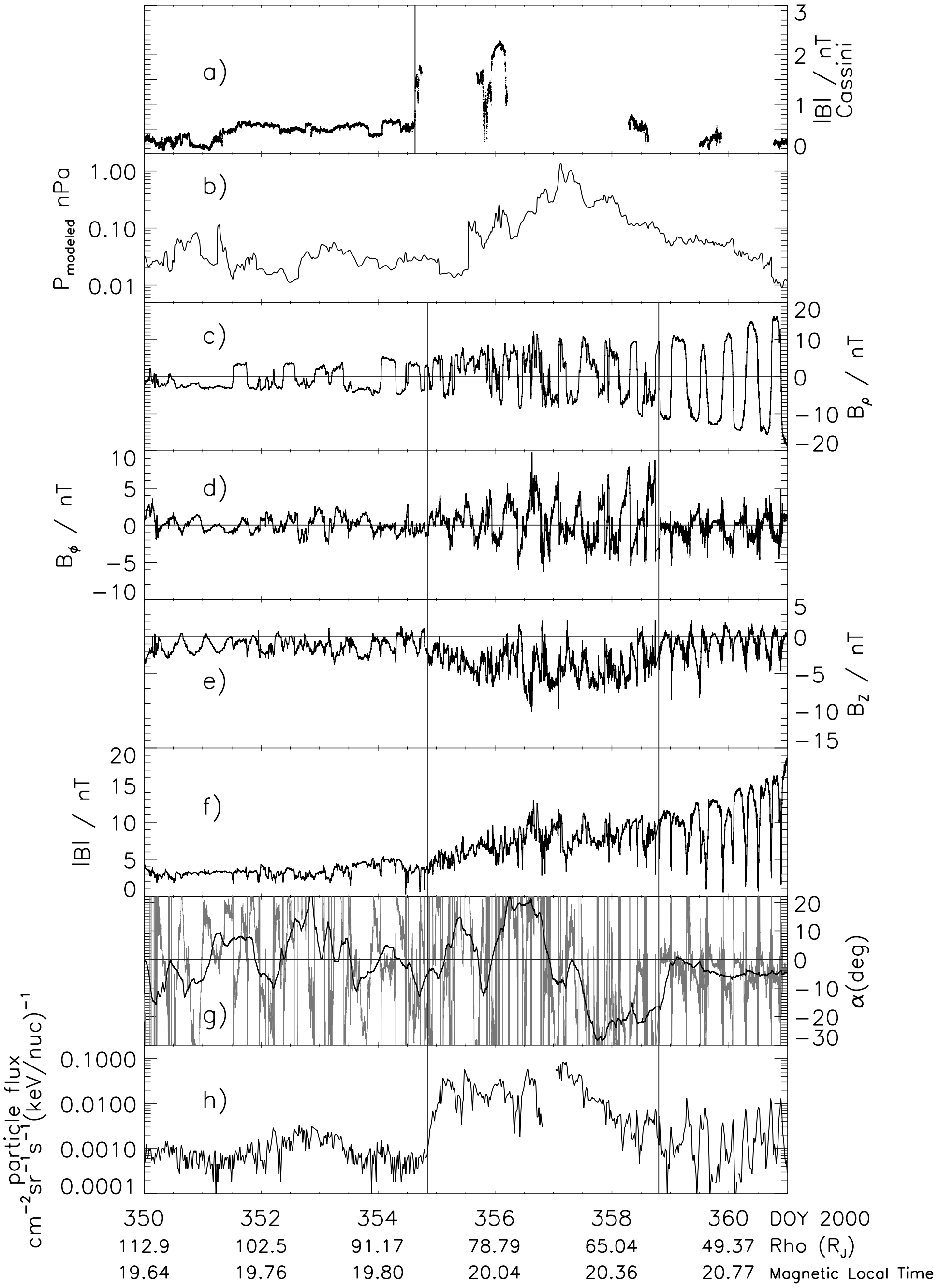

Figure 2. (a) The magnetic field magnitude as measured by Cassini on its Jupiter approach. (b) The predicted interplanetary dynamic pressure as obtained from an MHD model. (c–e) The three magnetic field components as measured by the Galileo MAG instrument, plotted in a cylindrical polar coordinate system centered on the planetary dipole axis (ρ, φ, and z, respectively). (f) The field magnitude. (g) The azimuthal pointing angle of the field (defined in text, the darker trace shows the result of smoothing over a planetary rotation). (h) An omnidirectional flux of 1.68–3.20 MeV ($Z \geq 1$) energetic particles as measured by the Galileo EPD instrument. The vertical line in the top panel represents the onset of an interplanetary shock at Cassini and the vertical lines in the remaining panels bound a later compression event at Jupiter.

increased from −2 to −5 nT on average, peaking near the center of the event. This preferential increase in the magnitude of the Bz component is expected for such magnetospheric compressions and represents a less radially distended field geometry, as is shown schematically in Figure 2 of *Southwood and Kivelson* [2001]. This can be understood in terms of a combination of increased magnetopause field components and a change in the magnetic field structure produced by azimuthal currents flowing within the equatorial plasma sheet.

[10] Figure 2g shows the angle α (=$\tan^{-1}[B\varphi/B\rho]$), which is often used to describe the sense of "lag" or "lead" of the

magnetic field within the Jovian magnetosphere. So α is measured from the positive radial direction toward the positive φ direction, hence positive values of the angle denote fields that "lead" the normal dipolar direction and negative values denote "lagging" fields. The lighter trace shows the high-resolution (24 s) data and the darker trace shows the result of applying a boxcar average of one planetary rotation (taken to be 9 hours 55 min 29 s); this will be discussed below. A similar approach has been recently utilized by *Kivelson et al.* [2002], who examined an extended departure of the Galileo spacecraft from the plasma sheet. This revealed a latitudinal dependence of the azimuthal pointing direction of the magnetic field, indicative of a sheared magnetic structure in the duskside magnetosphere. The interpretation given to this observation was that as the spacecraft oscillated in latitude (with respect to a coordinate system centered on the planetary dipole axis), it was sampling either low-latitude field lines that threaded through the plasma sheet (which lag the normal dipolar direction due to the subcorotation of the equatorial plasma) or the higher-latitude field lines which map out to the magnetopause (which lead the normal dipolar direction due to being "dragged" antisunward as they are connected to the interplanetary magnetic field).

[11] As the magnetosphere is compressed, the plasma sheet is expected to thicken [*Southwood and Kivelson*, 2001]. For example, a compression of the magnetosphere by a factor of 2 in linear dimension is expected to cause the plasma sheet to thicken by a factor of 1.7 (here we correct a typographical error in the work of *Southwood and Kivelson* [2001] where the factor $4^{2/5}$ was quoted as 2.5 rather than 1.7). So, if we were indeed observing a compression of the magnetosphere, we would expect the spacecraft to be less likely to exit the plasma sheet. This is indirectly evidenced by the observation that we see definite "square-wave" lobe-magnetodisk-lobe type signatures both prior and subsequent to the compression event and almost no evidence of this while the system is compressed. There are other possible reasons for the more structured magnetic field observed during this compression event, such as distortion of the plasma sheet by the compression itself or the production of local instabilities by the preferentially perpendicular heating of the plasma expected in such a scenario. Discussion of these effects is beyond the scope of this paper. However, as is demonstrated clearly in Figure 2 of *Kivelson et al.* [2002], even if the observed field is disturbed, α can provide information about the general azimuthal pointing direction of the field. With this in mind, we examine the lighter (averaged) trace of α as measured by Galileo (Figure 2g). The averaging employed here should not only smooth out any short-term variations in the field but should also remove to some extent any latitudinal variation in the field direction encountered. It should be noted that the positive values of the angle α observed during this interval are very rare within the Galileo data set. The positive values that occur before the compression event encompass periods, which as mentioned previously, were interpreted by *Kivelson et al.* [2002] as signatures of a sheared field structure. We will argue that the positive values of α observed during the onset of the compression event are signatures of supercorotation due to conservation of angular momentum of the magnetospheric plasma as the system was compressed.

[12] It can be seen that within the period of increased field magnitude bounded by the vertical lines, the value of α, although changing sign briefly on day 355, was on average positive for the first half of the event, indicating leading fields. After the start of day 355 the angle increased for 1 (Earth) day, being strongly positive for almost all of this period, before reducing and switching sign at approximately the start of day 357 to remain strongly negative until the end of the event. After the end of the compression event, the angle settled to the generally lagging configuration normally expected and remained so for the remaining data set plotted. We will note that the period of intensely leading field lasted for approximately 1 day, beginning near the start of day 356.

[13] The bottom panel of Figure 2 shows a plot of the omnidirectional flux measured by a selected energy channel (A7, 1.68–3.20 MeV, $Z \geq 1$) of the Energetic Particles Detector (EPD) instrument [*Williams et al.*, 1992] aboard Galileo. Only one channel is shown for clarity, but all energy bands show the same pronounced increase in flux throughout this compression event. This is entirely consistent with a compressed and heated plasma, assuming adiabatic (betatron) acceleration.

[14] As the field and plasma are frozen together, we expect any variations in the azimuthal pointing of the field to be associated with changes in the azimuthal plasma flow. An approximation to the bulk plasma velocity at the spacecraft can be obtained by examination of the first-order anisotropies of the energetic particles. Plotted in Figure 3b (dashed line) is the azimuthal plasma velocity deduced from EPD; the solid trace shows the field angle α that was shown in Figure 2. The vertical lines again bound the period defined as the compression event. As can be seen, a large increase in velocity was observed during the onset of the compression event, this being consistent with expectation.

[15] In the steady state we expect a relationship to exist between the azimuthal plasma velocity and the "bend back" angle of the magnetic field, i.e., the more the equatorial plasma lags corotation, the greater the azimuthal field component that will be produced. Figure 3a shows a scatterplot of the field angle and azimuthal velocity. A linear (Pearson) correlation coefficient of only 0.04 exists between the two properties. An explanation for this negative result may lie in the fact that as can be seen from Figure 3b, both the field angle and plasma velocity are variable on timescales smaller than the 20 hours predicted for the magnetosphere-ionosphere (M-I) coupling system to achieve equilibrium [*Cowley and Bunce*, 2003a]. Therefore we expect the system to be in a state of constant reconfiguration and hence for a relationship to exist between the rate of change of the pointing angle and the azimuthal velocity, i.e., the larger the variation in velocity from the initial condition, the faster the field-pointing direction will be changing. If we consider a parcel of plasma that is moving at an azimuthal velocity u_0, threaded by a field line that is initially at an angle α_0 to the radial direction (keeping to our above definition of α), then as the velocity changes to u_1 (where $u_1 > u_0$), the field angle will initially begin to become more positive until it reaches its peak for that particular compression. Subsequently, if no further variations occur in the external pressure, the field angle will tend

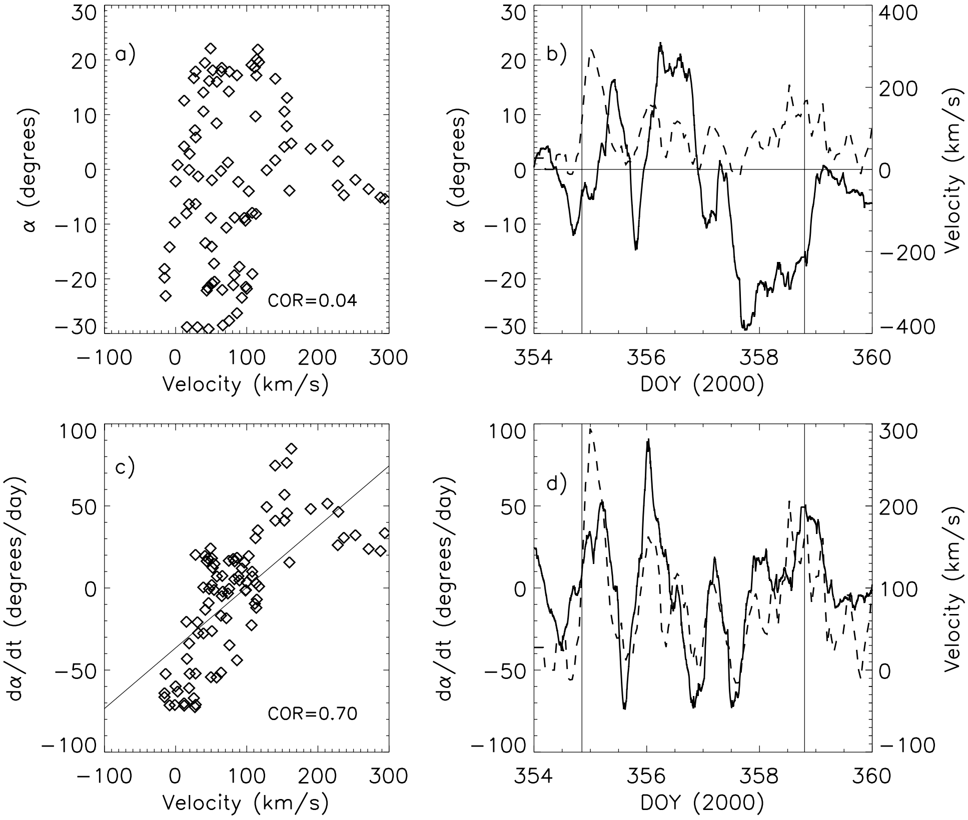

Figure 3. (a) A scatterplot of the magnetic field angle α (measured by the Galileo MAG instrument, defined in text) and the azimuthal plasma velocity determined from energetic particle anisotropies (as measured by the Galileo EPD instrument). A linear correlation (COR in figure) of only 0.04 exists between these data. (b) A time series plot of the two data sets shown in Figure 3a; the dashed trace represents velocity and the solid trace represents α. The vertical lines bound a region defined as a compression event at Jupiter (see text). (c) A scatterplot of dα/dt (the change with respect to time of the magnetic field angle α), and the azimuthal velocity. A least squares determined line of best fit has been drawn through the data, with a linear correlation coefficient of 0.70 existing between the two properties. (d) A time series plot of the two data sets represented in Figure 3c. The dashed trace again represents plasma velocity and the solid trace represents dα/dt. The vertical lines are as in Figure 3b.

to lag more strongly with time (as the Iogenic plasma diffuses radially outward), until equilibrium is achieved. Figure 3d shows both the azimuthal plasma velocity (again the dashed trace) and dα/dt (computed from the averaged value of α and given in units of degree per day). This provides a measure of how fast and in which sense the azimuthal pointing direction of the magnetic field is changing. By inspection, we can see that a much better correlation exists between these two properties and those plotted in Figure 3b. Figure 3c shows dα/dt plotted versus plasma velocity for all of the data points contained within the vertical lines in Figure 3d. A positive correlation with a linear correlation coefficient of 0.70 exists between the two quantities during this compression event.

[16] We could conjecture that the zero value of dα/dt (Figure 3c) may correspond to some average value of flow at this point, as this is the value of velocity that on average does not perturb the field pointing direction, i.e., the local average subcorotation velocity. Reading from the least squares determined line of best fit yields a value of 88 km s^{-1} corresponding to dα/dt = 0, this is approximately half the velocity predicted in this radial range by theory [*Cowley and Bunce*, 2003b] and represents approximately $0.1\Omega_J$, where Ω_J is the rotation frequency of the planet. This is consistent with previous studies of plasma velocities examining the first-order anisotropies of energetic particles in this radial range and local time [*Krupp et al.*, 2001].

3. Discussion

[17] The difference in time between the onset of the solar wind event observed by Cassini and the onset of the compression event observed by Galileo is 5.22 hours, which implies an antisunward speed of the event of close to 650 km s^{-1}. This is slightly higher than the 600 km s^{-1} predicted by the MHD model for this event but is well within the range of velocities expected for transient solar wind events at this heliospheric distance.

[18] Data that are available from the CAPS-IBS instrument aboard Cassini for the period directly prior to this event (which are limited in temporal coverage due to pointing restrictions) indicate that the dynamic pressure was holding steady at values on the order of 0.01 nPa (very consistent with the MHD model). This indicates a subsolar

magnetopause at approximately 98 R_J [*Huddleston et al.*, 1998] and the edge of the magnetosphere-ionosphere (M-I) coupling system to be at 74 R_J [*Cowley and Bunce*, 2003b]. As stated above, the approximate change in the Bz component due to the compression is 3 nT, changing from −2 nT prior to the event to −5 nT after the event. In the recent theoretical work of *Cowley and Bunce* [2003b] a variable addition/subtraction to the Bz field is used in order to simulate magnetospheric compressions within their formulation. Examination of Figure 4 of *Cowley and Bunce* [2003b] reveals that an increase from the initial value by 3 nT would be equal, in their theory, to a compression of the magnetosphere that pushed the outer edge of the magnetosphere-ionosphere coupling system to approximately 35 R_J and the magnetopause to approximately 47 R_J, a highly compressed state. This would imply an external pressure of 0.22 nPa, which is very close to that predicted by the MHD model for most of the duration of the event. This indicates that the observed compression is on the order of a factor of two in linear dimensions, similar to that discussed theoretically by *Southwood and Kivelson* [2001].

[19] Figure 4a shows the correlation between the modeled external pressure and the field angle at Galileo as a function of the time shift applied to the pressure time series. A maximum linear correlation of 0.72 exists between the two if the onset of the shock wave is shifted by −0.7 days. This represents moving the predicted onset of the interplanetary shock wave to almost exactly where we have drawn the first vertical line to indicate the start of the compression at Galileo. Figure 4b shows a time series plot of the field angle (solid trace) and the modeled pressure (dashed trace) after applying this time shift of −0.7 days. As can be seen, increases in external pressure generally coincide with periods where the field angle is more positive. Figure 4c shows a scatterplot of the data bounded by the vertical lines in Figure 4b, which represent the period defined previously as a compression event within the system. This positive correlation between the modeled external pressure and the magnetic field pointing angle at Jupiter provides indirect evidence that increases in external pressure are indeed accelerating the magnetospheric plasma, as expected.

[20] *Cowley and Bunce* [2003a] examined theoretically not only the steady state response of the system to changes in external pressure but also its expected transient reactions. For a compression that takes the outer edge of the M-I coupling system to 35 R_J or closer from an extended state, significant supercorotation is expected. Hence as the field and plasma are frozen together, leading field directions are also expected. After the onset of the compression it is predicted that the system will take approximately 20 hours to achieve a new equilibrium angular velocity profile.

[21] Examination of the data presented in Figure 2 provides us with a tantalizing if not entirely conclusive opportunity to test some of the above predictions. As stated previously, the amount by which the field increased (Bz component) was consistent with both the above theoretical work and the modeled external pressure increase. Also as predicted, leading field angles were observed, at least for the first half of the event. After day 357 the angle of the field tended back toward a lagging configuration (indicating subcorotation), which was predicted in the steady state for all compressions as the Iogenic plasma begins once again to reduce in angular velocity as it diffuses radially outward. This lagging effect would be compounded if the system were expanding back to an uncompressed state, as is suggested by the slow decrease in pressure predicted by

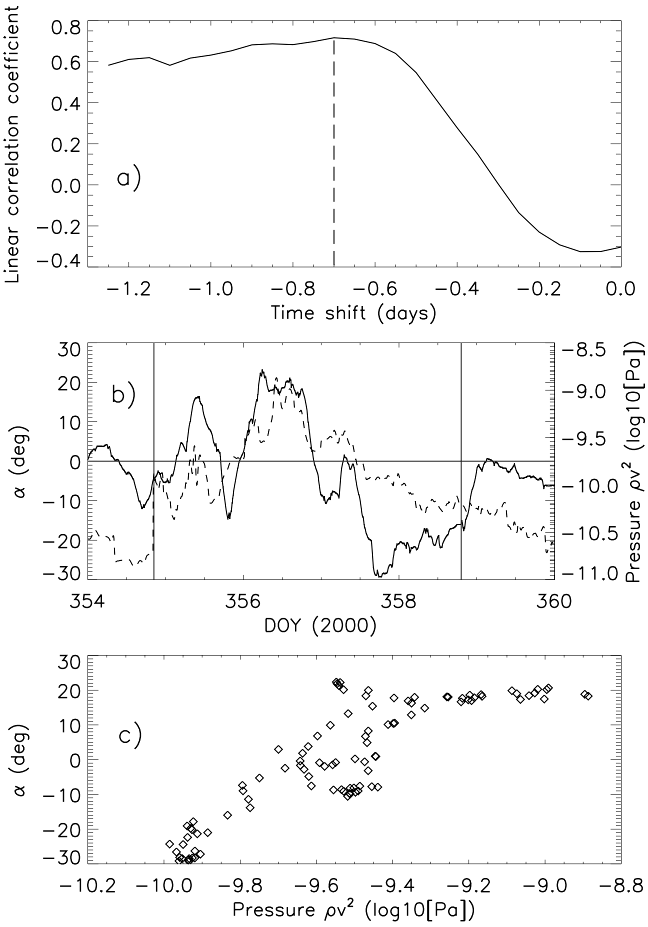

Figure 4. (a) How the linear correlation coefficient varies between the Jovian magnetic field pointing angle α (measured by the Galileo MAG instrument), and an MHD model of the solar wind dynamic pressure as the temporal offset between the two time series is altered (α is defined in the text and measured in degrees, the pressure has been taken as log10[Pa] for the purposes of the correlation calculation). A vertical line has been added to highlight the maximum correlation (0.72), which occurs when a temporal offset of −0.7 days is applied. This time shift represents moving the predicted onset of an interplanetary shock wave to almost exactly the point that we interpret to mark the onset of a compression event at Jupiter (see text). (b) A time series plot of the two properties correlated in Figure 4a after the time shift which represents the maximum correlation has been applied to the pressure trace. The solid trace represents the field angle α and the dashed trace represents the predicted solar wind pressure. As can be seen, after this time shift has been applied, increases in the external pressure coincide with periods where the pointing angle was becoming more positive. The vertical lines bound the period interpreted as a compression event within the magnetosphere. (c) A scatterplot of the field angle and the external pressure data bounded by the vertical lines in Figure 4b.

the MHD model approximately 2 days after the shock arrived. This conjecture is supported by the observation that the flux of energetic particles began to reduce back to the precompression value at almost exactly the same time that the field angle flipped to a lagging pointing direction.

[22] This strongly lagging configuration in the reexpansion phase of the compression event is to be expected if the magnetospheric plasma was indeed driven into supercorotation. This would have caused a magnetosphere-ionosphere coupling current system to be driven in the reverse sense to normal [*Cowley and Bunce*, 2003a]. This in turn would cause the magnetospheric plasma to lose energy and angular momentum to the ionosphere, via field aligned currents, until corotation (and subsequently subcorotation) was achieved either by this loss to the ionosphere or by the slowing of the material due to radial diffusion. Therefore when this plasma that has been tapped of angular momentum subsequently reexpands, it will reduce in angular velocity to a value below that which it had originally prior to the compression. Hence it will lag strongly and drive very bright aurorae until the steady state is once again achieved.

[23] A 20-hour timescale for the steady state situation to evolve in the magnetosphere-ionosphere coupling system was predicted by the above theoretical work. As stated previously, Figure 2g shows that over 2 days passed from the start of the event until lagging fields were once again observed. However, the most strongly leading fields observed from near the start of day 356 did indeed last for almost exactly this 20-hour time period. We could conjecture that as predicted by the MHD model, the greatest increase in external pressure did not occur until 1 day after the start of the event and that this is why the most significant signatures of leading fields were observed after this time and that then the system took the prescribed 20 hours to fall back to the steady state. This however, may be pushing reliability of the MHD model past that which we should in the absence of actual measurements of bulk plasma moments for this time period.

[24] Although all of the above observations are entirely consistent with the concept of conservation of angular momentum within the Jovian system, two factors must be considered before we decide exactly how to interpret these data. First, the radial range that the spacecraft was traversing during the compression event was approximately 85–55 R_J. This would mean that the spacecraft was at the very outer edge of where both observation and theory [see *Cowley and Bunce*, 2003b, and references therein] suggest that the M-I coupling system extends. We must remember though that the Jovian system was in a highly extended state during the Cassini flyby [*Kurth et al.*, 2002; M. K. Dougherty et al., Cassini's view of Jupiter's magnetic environment, submitted to *Journal of Geophysical Research*, 2004], with very low solar wind pressures causing bow shock crossings to be observed past 140 R_J. We would expect then for the M-I coupling system to be scaled to this inflated state. In addition, these observations were taken while the spacecraft was in the evening sector of the magnetosphere, and presumably as with many other magnetospheric features, we must allow for the M-I coupling system to extend further on the nightside due to the asymmetric confinement that the solar wind imposes upon the system. The second important point to note here is that there is one possible alternative interpretation of the above data that does not rely upon invoking the M-I coupling system. Owing to the position of the spacecraft within the magnetosphere during this compression event, the azimuthal and antisunward directions are fairly well aligned, being only a few tens of degrees apart. This means then that we may in fact be simply observing the magnetospheric plasma being pushed antisunward each time the external dynamic pressure increases and returning sunward as the external pressure relaxes. If the spacecraft were on the dawnside of the system, then we would be able to decouple these two effects, and if indeed increased sunward flow were observed for an increase in external pressure, then we would be sure that we were in fact observing effects due to conservation of angular momentum.

4. Summary

[25] Dual-spacecraft observations have been presented of a compression event within the Jovian magnetosphere. The onset of an interplanetary shock wave can be clearly seen within the Cassini magnetometer data. An approximation to the solar wind dynamic pressure that would be expected during this event was obtained by using an MHD model of solar wind properties that were propagated from the Earth, which was fortuitously within a few tens of degrees of Jupiter in heliospheric longitude.

[26] In situ measurements taken by the Galileo spacecraft reveal that when this interplanetary event reached the magnetosphere, it compressed and heated the magnetospheric plasma (as observed by the EPD instrument). In addition, the magnetic field at Galileo was seen to increase in magnitude, particularly the B_z and B_φ components.

[27] Comparisons of observations with recent theoretical modeling of the magnetosphere-ionosphere coupling system have been made with positive results. The amount by which the field (B_z component) increased during the compression and the modeled external pressure are independently consistent. Leading fields were observed during the onset of the event, which was predicted theoretically for a compression of this magnitude. As the modeled dynamic pressure and energetic particle flux began to drop, the field tended back toward a lagging configuration, which is consistent with the concept of conservation of angular momentum within the magnetosphere-ionosphere coupling system.

[28] More data sets are available for this time period and may be able to shed light on the detail of this event, such as any density changes that occur at Jupiter during the compression, the change in the actual velocity and energy distribution of the magnetospheric plasma, and also the density of the solar wind as the event passes over Cassini. Also, any auroral and radio observations that exist for this period may prove insightful. Examination of such additional information as well as a comparison with previous data sets in this radial range and magnetic local time will be the subject of a more comprehensive study.

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