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Production and Propagation of the Jupiter Radio Signal in the Jovian Magnetosphere

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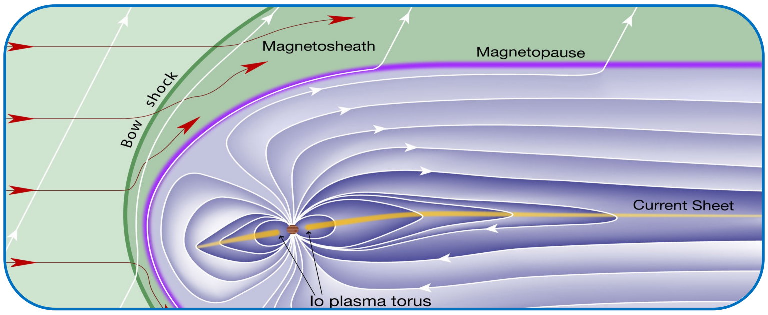
Abstract

- This study is an investigation into the behaviour of the Jovian narrowband kilometric radio emission (nKom) during periods of magnetospheric compression.
- Using the findings from Hospodarsky et al. (2017), and the Joy et al. model, four periods of magnetospheric compression have been identified.
- It is found that the compression of the Jovian magnetosphere by the solar wind results in the activation of nKom sources and that the emissions observed during compression typically occur in bursts, with two or three bursts observed throughout a compression period.
- The emissions display a ten-hour periodicity which indicates that the emission source is longitudinally fixed and rotating with Jupiter.
- nKom emissions are observed to change frequency after several rotations which is believed to be as a result of the emission source moving to areas of higher or lower plasma density inside the Io torus.
- From the findings in this study, it is concluded that observations of nKom emission may be used as a proxy for solar wind conditions at Jupiter.

Boundaries of the Magnetosphere

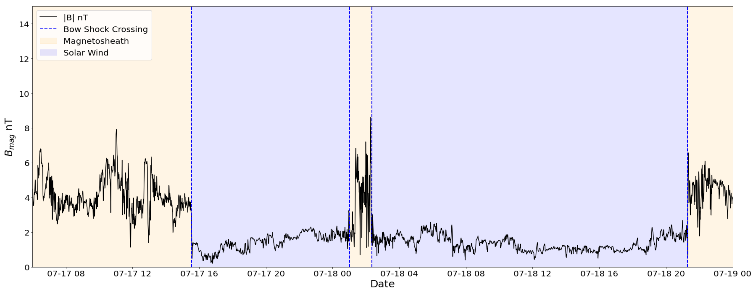
- There are two key boundaries of the magnetosphere. The bow shock and the magnetopause.
- The magnetopause is the boundary which the solar wind cannot penetrate due to the interaction of the solar wind's magnetic field and that of the magnetosphere.
- The bow shock is created when the solar wind meets the magnetopause and its speed drops suddenly. This creates a shock further upstream of the magnetopause which is known as the bow shock.
- The area in between the bow shock and the magnetopause is the magnetosheath. it is composed of slowed and compressed solar wind.



An image of Jupiter's magnetosphere with the key boundaries (bow shock and magnetopause) labelled (Bagenal and Bartlett)

Identifying Boundary Crossings

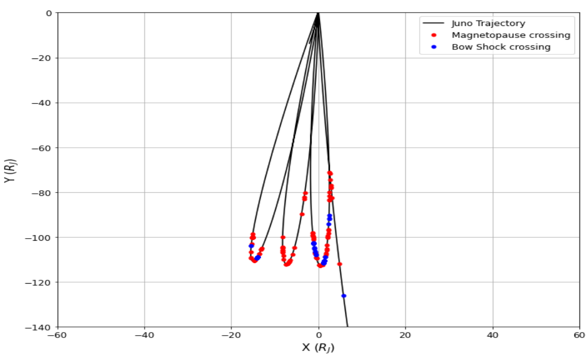
- In order to determine when the Juno spacecraft crosses a boundary, the magnetic field magnitude data recorded by the magnetometer onboard is analysed.
- When the spacecraft is in the magnetosheath, the field magnitude fluctuated rapidly.
- When the spacecraft is in the Solar wind, the field magnitude is relatively stable and has lower values then when in the magnetosheath.
- In the inner magnetosphere, the field magnitude is typically higher and slightly more stable then in the sheath.



The magnitude of the Jovian magnetic field (black line) from 17/07 (DOY 199) until the end of 18/07 (DOY 200). Here the magnetic field magnitude has been used to determine the region at which the spacecraft crosses the bow shock boundary (blue dashed lines).

Juno's Orbital Path

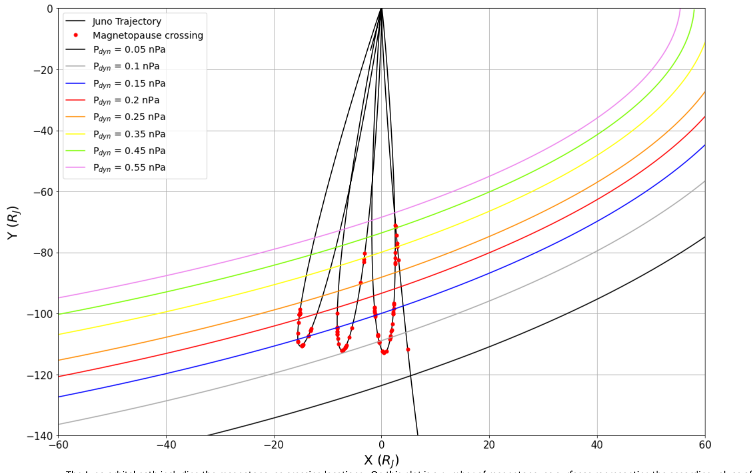
- A paper published by Hospodarsky et al. (2017); used the above method to determine the time and location of the boundary crossings. for Juno's approach to Jupiter and for the first three orbits after JOI.
- In the study, a total of 97 magnetopause crossings and 51 bow shock crossings were identified.
- The location of the spacecraft (in JSO coordinates) during each of these crossings could be established by comparing the time each crossing occurred at with the Juno position telemetry.
- This meant a visual tool displaying the Juno orbital trajectory with each magnetopause and bow shock crossing could be created.
- This figure is used in establishing periods of magnetospheric compression.



The orbital path of the Juno spacecraft for its approach to Jupiter and its first three orbits in the XY plane(black line). Plotted onto this is the position the spacecraft crossed the magnetopause (red dots) and the bow shock (blue dots) boundaries.

Determining Periods of Compression

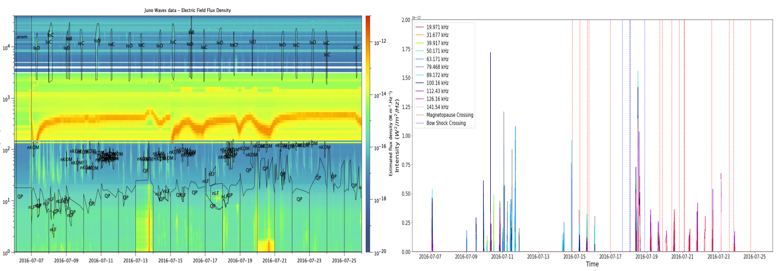
- By using the Joy et al. model in conjunction with the identified boundary crossings, periods of magnetospheric compression can be found (Joy et al, 2002).
- The Joy et al. model takes an X, Y, Z coordinate and returns a value of solar wind dynamic pressure
- By inputting the coordinates of boundary crossings, the Joy et al. model will fit magnetopause and bow shock surfaces to intersect with the given coordinates.
- The model will also return a dynamic pressure value that corresponds to the boundary surface existing in this location.
- Thus, the solar wind dynamic pressure value that was responsible for the position of each boundary crossing can be attained.
- Joy et al, (2002) details that a compressed magnetopause had an associated dynamic pressure value of 0.306 (+0.108, -0.078) nPa.
- Comparing the dynamic pressure values for each crossing with the associated values of a compressed magnetopause is the primary method of identifying compression in this study.



The Juno orbital path including the magnetopause crossing locations . On this plot is a number of magnetopause surfaces representing the according values of dynamic pressure. These surfaces have been obtained using the Joy et al. model

Analysis of nKom During Compression

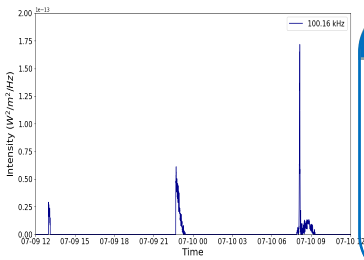
- In total, four periods of magnetospheric compression were identified in this study.
- During each of these compressions, the nKom emission has been analysed using dynamic spectra and time series figures.
- Dynamic spectra are a time/frequency map with the frequency of the radio waves on the Y-axis on a logarithmic scale and time on the X-axis. The flux density of the emission is described by a colour map.
- Time series figures display the variation in time of the intensity of specific frequencies of radio emission.



The dynamic spectrum (top) and time series (bottom) for the second magnetospheric compression identified (DOY 188 - 207). In the dynamic spectrum, the instances of nKom emission have been labelled (Louis et al. catalogue, 2021b.). In the time series, the magnetopause and bow shock crossings are indicated by the red hatched lines

Results

- Unfortunately, the Juno Waves instrument was not operating during the first identified period of compression and thus, no data is available for this period.
- During analysis of the emission during the second, third and fourth compressions, it was evident that compression of the magnetosphere activates sources of nKom emission.
- During each compression, it was common to observe multiple bursts of emission.
- In each burst, individual emissions were often observed to exhibit a ten-hour periodicity indicating that the source of the nKom emission was longitudinally fixed.
- The rotation of Jupiter is approximately 10 hours and therefore, as the source has fixed longitude, the emission is observed as it comes into view of Juno as it rotates with the planet.
- The emissions often displayed a shift in frequency in time, changing to higher/lower frequencies with each rotation. As nKom is emitted at the plasma frequency, (which is related to the plasma density) the observed shift in frequency is likely as a result of the emission source moving to an area of higher or lower plasma density inside the Io torus.



Time series of the 100.16 kHz frequency band over the course of DOY 190 (second compression).

Conclusions

- The Jovian nKom emission has been analysed during each of these periods of compression and it has been determined that compression of Jupiter's magnetosphere by the solar wind results in the activation of nKom sources.
- During periods of compression, nKom emissions typically display ten-hour periodicity as a result of the source being longitudinally fixed.
- The frequency of emission is subject to change, as the source moves into locations of higher and lower plasma density in the torus.
- Further work in this area may include the study of further Juno orbits past the initial three to identify more periods of compression and examining the periodicity of the nKom emission more closely. The findings presented in this study imply that nKom emission may be used as a proxy for the solar wind conditions at Jupiter.