Investigating the Contribution to the Magnetic Field of Jovian Planets by Parahydrogen Interactions

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Abstract: In this poster, we present a pathway for investigating the potential contribution to planetary magnetic fields from parahydrogen in Jovian planets, specifically on Jupiter. By cross referencing scientific journal articles pertaining to parahydrogen concentrations within Jupiter, we analyze planetary models, dynamo theories, and known wind channels relevant to the flux of parahydrogen. Techniques of interest include Raman Scattering to identify and quantify hyperpolarized regions of the outermost planetary layers.

Research: The origin of the magnetic field of Jovian planets is still up for debate within the astronomy community. One particular self consistent model theorizes that Jupiter has three distinct layers (Kong et al. 2016).

- Outermost envelope is known to be a molecular gas cloud, its surface denoted as S_o.
- Confined to the outermost layer of Jupiter, between S_o and S_m are cylindrical zonal winds parallel to the planet's axis of rotation that successively alternate in direction (see Figure 1).
- It is assumed that these cylindrical winds extend undiminished from the metallic molecular interface to the outermost surface; however, this remains to be proven experimentally.
- The middle layer is a metallic hydrogen-helium dynamo, its surface denoted as S_m.
- The final layer is a small rocky core, its surface denoted as S_c.
- The metallic hydrogen-helium dynamo can be envisioned as a churning flow of particles similar to Earth's liquid iron outer core taking place between S_c and S_m; this gives rise to magnetic braking which keeps the zonal winds from penetrating the metallic molecular interface, S_m.
- The dynamo theory does not shed light on the fact that the magnetic field is tilted in reference to the axis of the planet's rotation nor yields insight to the complex multipolar magnetosphere (Chekmenev 2020).
- In the troposphere of Jupiter, aerosols catalyze a nuclear spin exchange process from parahydrogen to bulk-aligned orthohydrogen ('hyperpolarized').
- Bulk orthohydrogen molecules may create a hyperpolarized region in the atmosphere alongside the cylindrical zonal winds—contributing to the Jovian magnetic field.

Fig. 1 (Kong et al. 2016)

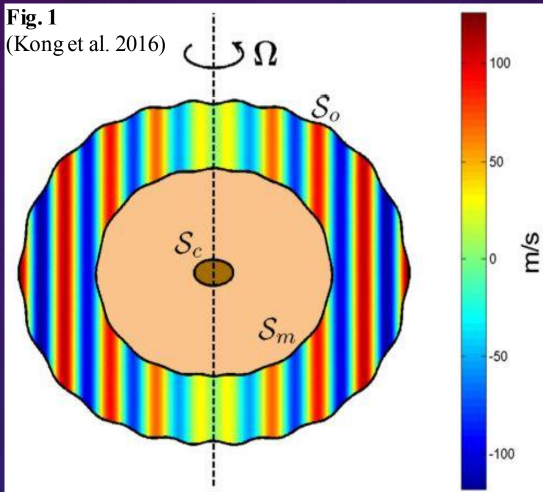
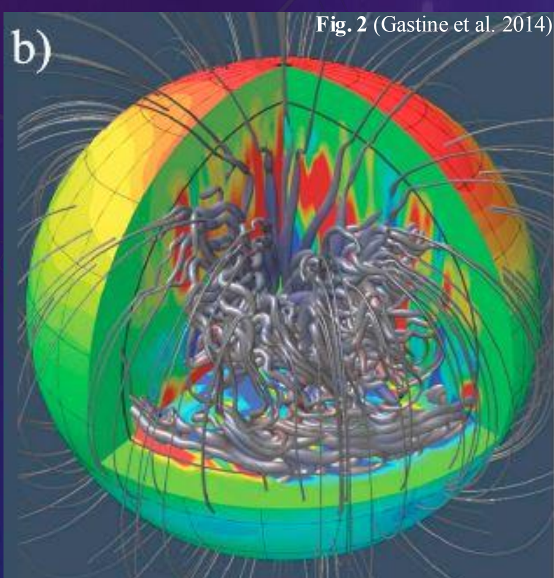


Fig. 2 (Gastine et al. 2014)



Conclusions: I postulate that the magnetic field produced in the metallic molecular hydrogen layer is irregular in structure due to complex dynamo convection currents. Perhaps induction due to the cylindrical winds, the interactions between the zonal winds, equatorial jets, and induced bulk hyperpolarization of the outer atmosphere all contribute to force the magnetic field into a more uniform and conventional shape (see Figure 2).

- Ultraviolet light is a catalyst for parahydrogen to orthohydrogen spin conversion (Osterbrock 1962) so regions of hyperpolarized orthohydrogen may be significantly larger and more prominent on the side of the planet facing the Sun.
- It is understood that unless the deep-seated dynamo magnetic field is unreasonably strong, the surface planetary magnetic field is dominated by the [atmosphere's] induced field (Rogers & McElwaine 2017).
- In the polarized configuration, in which the incoming and the outgoing light have the same polarization, Raman scattering probes charge-density fluctuations (Aku-Leh et al. 2018). Raman scattering can be used to differentiate para and ortho configurations of hydrogen gas in the Jovian atmosphere.
- I propose that *in situ* Raman scattering in Jupiter's atmosphere via spacecraft may be a purposeful tool to validate or disprove this theory as it can accurately probe the para-to-ortho spin states of hydrogen gas.
- In the future, those with access to such equipment may acquire indicative physical data that can help to validate or disprove the current theoretical framework.

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References:

Aku-Leh, C., Jusserand, B., et al., "Measuring the Spin Polarization and Zeeman Energy of a Spin-Polarized Electron Gas: Comparison Between Raman Scattering and Photoluminescence," Physical Review B, vol. 76, no. 15, 2018, pp. 1-13.

Chekmenev , E., "Parahydrogen-Induced Magnetization of Jovian Planets?" ACS Earth Space Chemistry, vol. 4, 2020, pp. 495-498.

Gastine, T., Wicht, J., et al., "Explaining Jupiter's Magnetic Field and Equatorial Jet Dynamics," Geophysical Research Letters, vol. 41, 2014, pp. 5410–5419.

Kong, D., Schubert, G., & Zhang, K., A Fully Consistent Multi-layered Model of Jupiter, The Astrophysical Journal, vol. 826, no. 2, 2016, pp. 1-8.

McElwaine, J. N., & Rogers, T. M., "The Hottest Hot Jupiters May Host Atmospheric Dynamos," The Astrophysical Journal Letters, vol. 841, no. 2, 2017, pp. 1-6.

Osterbrock, D. E., "On Para- and Orthohydrogen Molecules In Interstellar Space," The Astrophysical Journal, vol. 136, 1962, pp. 359-362.