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The Rotation Period of Jupiter

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Abstract. The period with which radio bursts recur on Jupiter (the System III period) is defined by the IAU to be 9h 55m 29.71s based on early radio astronomical data, and is generally assumed to represent the period of rotation of the Jovian interior. A recent estimate of the System III period from radio burst data is 0.025s shorter than the IAU value. In apparent contradiction to the radio observations, in situ measurements of the rotation period of Jupiter using the orientation of the dipole moment are consistent with the original rotation period defined by the IAU and inconsistent with the suggested period decrease. Thus, the present IAU period should be retained as the best estimate of the rotation rate of the Jovian interior. Since the radio bursts are generated near the base of the Io field line while the dipole field is measured by Galileo near the equatorial plane, the difference between the two rotation periods could be explained if Jupiter's magnetic field is undergoing perceptible secular variation.

Introduction

Since Jupiter has no solid surface from which to determine the rotation rate of the interior of the planet, it has been traditional to use the period based on radio emissions as a proxy for the internally driven magnetic field. This period, called System III (1965), was defined by the IAU to be 9h 55m 29.71s corresponding to 870.536° of rotation per Earth day [*Dessler*, 1983]. Recently it has been suggested that the radio period could be as much as 0.025s shorter than this value [*Higgins et al.*, 1997]. A more direct method of determining the rate of rotation of the planetary magnetic field is to use the in situ measurements of the magnetic field obtained with Pioneer, Voyager and Galileo missions. It is important to know the correct rotation period of the interior of Jupiter in order to compare measurements obtained years apart and it is of interest to determine if the two methods of determining the rotation rate agree as they depend on different components of the magnetic field. The in situ measurements of the dipole field depend on the dipole field orientation and the radio measurements are sensitive to the low altitude field to which the high order components of the field contribute. The measurements of Pioneer and Voyager were obtained in the 1970's and used as the basis of the O6 model of the magnetic field [*Connerney*, 1992]. The measurements by Galileo began in December 1995 and continue to the present. The radio observations were made over a 35-year period from 1957 to 1994 [Higgins et al., 1997].

The Longitude of the Magnetic Dipole Moment

System III coordinates, like most astronomically derived coordinates for prograde rotating bodies, are left-handed. However, since we use these coordinates in mathematical equations we prefer to use the right-handed variant of this system. Thus all angles we quote are in east longitudes. Based on the 1973 and 1974 Pioneer 10 and 11 data in to 2.8 and 1.6 Jovian radii (R_J) respectively and the 1979 Voyager 1 data to 5 R_J the O6 model places the projection of the Jovian dipole model at 159.9° ± 0.6° E in the rotational equator. We use the O6 model because it has a relatively fixed epoch and is the last model to use solely the Pioneer and Voyager data. We quote the error estimate of *Connerney et al.* [1982] since *Connerney* [1992] quotes no errors. Because the Pioneer data were obtained late in the year, we choose 1977 as the appropriate epoch for the combined Voyager and Pioneer data.

At this stage we do not attempt to fit all the external and internal terms of the magnetic field during the Galileo epoch. Rather we assume that the external field model of *Khurana* [1997] and the O6 octupole magnetic fields are correct and fit only the residual field. The external field appears to be quite stationary during this period. The term independent of radius was constant within about 10 nT from orbit to orbit. In the Galileo epoch measurements inside 8 R_J were not available until the 21st orbit in mid 1999. We examine data only inside 15 R_J and divide our analysis into orbits 1-20 and orbits >20. All the data on the former orbits were obtained outside of 9 R_J. We obtain a longitude of 160.4° ± 0.7° and 160.0° ± 0.7° for epochs 1998 and 2000 respectively. Weighting the points by their inverse error bars and least square fitting we obtain a change of 0.01° yr^{-1} since 1977, a value much less than the radio astronomical value of 0.22° yr^{-1}. These values are compared in Figure 1. The drift of the dipole field in System III coordinates is small, much less than the inferred shift in phase of the radio sources. In fact, a constant value of the longitude is consistent with these data.

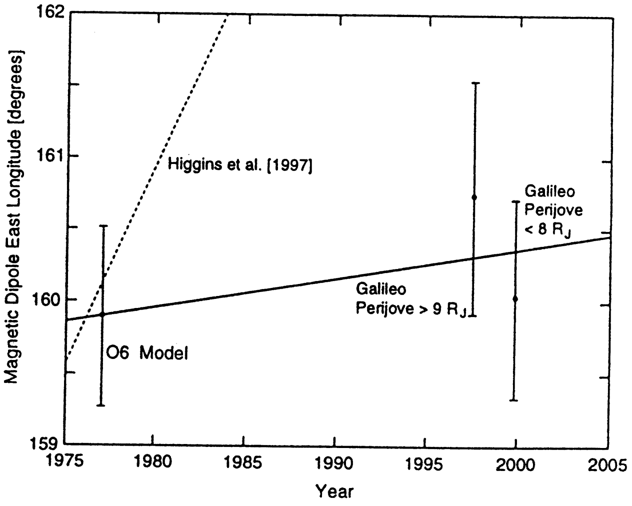

Figure 1. East longitude in System III (1965) of the dipole moment projected in the rotational equator of Jupiter from the O6 model (3) and from the Galileo observations at larger (>9 R_J) and smaller (<8 R_J) distances.

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We note that Ulysses passed through the jovian magnetosphere in 1992 with a perijove of 6.4 R_J. *Dougherty et al.* [1996] did not believe that they could improve the $g_1{}^1$ and $h_1{}^1$ terms of earlier models and they did not estimate the secular change in the longitude of the dipole moment. *Connerney et al.* [1996] do estimate $g_1{}^1$ and $h_1{}^1$ but give no estimate of error. Their longitude of 161.4° E with an error bar equal to that obtained herein from single Galileo orbits is certainly consistent with the O6 model and the average Galileo result as the error bar based on data from a single orbit would cover the full longitude range shown in Figure 1.

Summary and Conclusions

An earlier search for changes in Jupiter's internal magnetic field over a much shorter baseline produced a negative result [*Connerney and Acuna*, 1982]. The apparent drift of the jovian field reported by *Higgins et al.* [1997] would not necessarily be an indication of a possible change in the field, because it could simply indicate a needed correction to the System III period. However this proposed new period for Jupiter [*Higgins et al.*, 1997] is inconsistent with the change in the observed longitude of the projection of the dipole moment in Jupiter's rotational equator as measured by Galileo. We can possibly reconcile these two observations by invoking secular variation. Since the radio astronomical period is derived from phenomena near the visible surface of Jupiter that occur in high fields (1-12 Gauss) where higher order terms are more significant [e.g. *Wilkinson*, 1989], the difference in period obtained by the two techniques could indicate a difference in the evolution of the low order and high order fields over the last 25 years. Thus Jupiter's magnetic field may be undergoing perceptible secular variation.

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