The role of Corotation Enforcement Currents in driving the Behavior of Jupiter's Ultraviolet Main Emission

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December 16, 2021

Abstract

High-resolution observations made by the Hubble Space Telescope have developed the modern picture of the Jovian main oval emission as the signature of field-aligned corotation-enforcement currents which keep magnetospheric plasma rotating at the same rate as Jupiter's magnetic field. This model explains the slowly changing behavior and bright emissions of the main oval and allows the magnetosphere to be studied by remote observations, as the auroral oval directly reflects processes in the magnetosphere and properties of the plasma therein. Recent results from the Juno mission have called these results into question, as the strong, field-aligned currents required by the corotation-enforcement current system have not been measured. Where is the corotation-enforcement current– which must exist to move magnetospheric plasma– a dominant driver of the main oval emission? Where do other processes drive the main oval aurora instead? We present one of the widest surveys of Jupiter's main oval auroral features to date by combining over 180 hours of Hubble Space Telescope observations to address these questions. This comprehensive survey is the first to measure the corotation rate, an important tool for distinguishing auroral drivers, of all individual auroral features. This analysis is made possible due to the development of automated pipelines to reduce observations, produce keograms, identify discrete auroral emission features, and measure the corotation rates of these features, among other properties. We present the measured properties of emission features as a function of location along the main oval, in terms of longitude, local time, auroral local time, and magnetic local time. These results serve as the foundation for comparison to in-situ measurements from both the Galileo and Juno missions, which will ultimately help reveal which magnetospheric conditions are likely responsible for driving corotating emissions and which are responsible for sub-corotating emissions, such as the dawn storms.

THE ROLE OF COROTATION ENFORCEMENT CURRENTS IN DRIVING THE BEHAVIOR OF JUPITER'S ULTRAVIOLET MAIN EMISSION: INITIAL RESULTS

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12/15/2021

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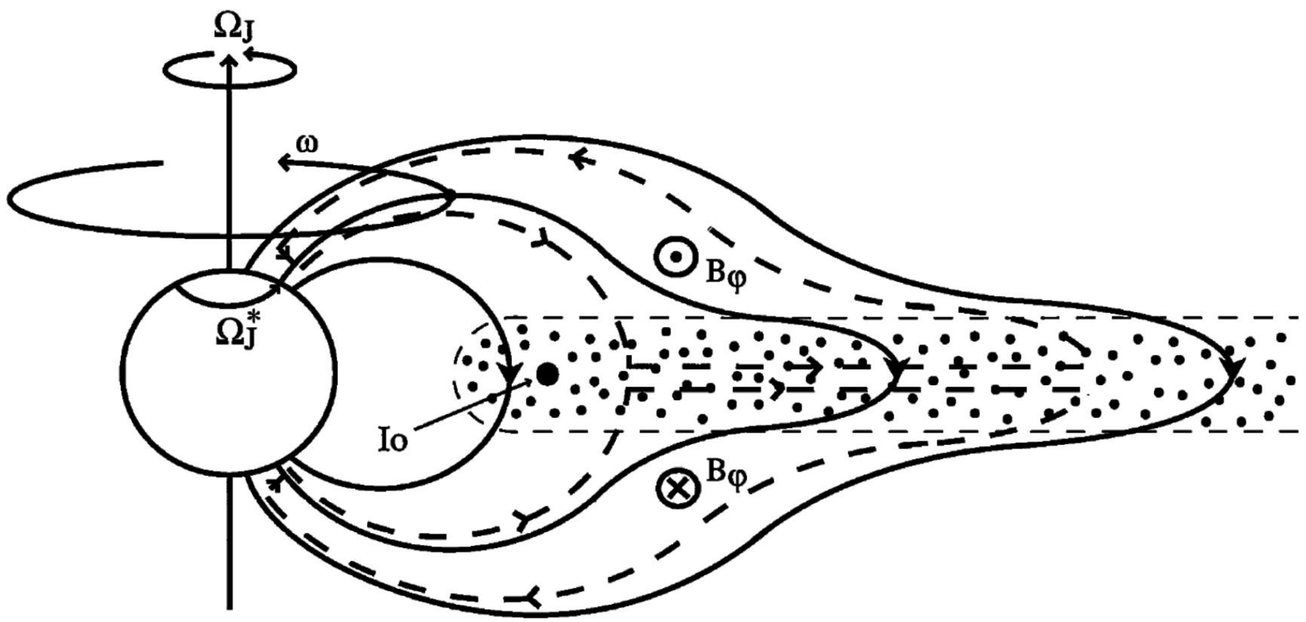
BACKGROUND + MOTIVATION

- Main emission classically driven by field-aligned corotation-enforcement currents (e.g. Hill 2001, Cowley + Bunce 2001, Southwood + Kivelson 2001)
  - Field-aligned currents enforce the corotation of magnetospheric plasma
  - Aurorae associated with downward electron flux from upward ionospheric currents
- Not apparent in *Juno* data to date
  - Bidirectional electron flux (Mauk + 2018)
  - Fragmented currents (Bonfond + 2020)
- Where are corotation-enforcement currents the dominant driver of the main emission?



From Cowley + Bunce 2001

SCIENCE QUESTIONS

- Where do the properties of Jupiter's main emission correlate with the predictions of corotation-enforcement theory?
  - Can we measure auroral properties accurately enough to answer this?
  - What correlations are expected?
    - $I_{||} = 4\Sigma_P^*(\Omega_J - \omega)F_e$ (Cowley + Bunce 2001)
      - $I_{||} \propto (\Omega_J - \omega)$
        - » Auroral intensity ∝ - plasma velocity
      - $\frac{d}{dt} I_{||} \propto \frac{d}{dt}(\Omega_J - \omega)$
        - » Auroral velocity ∝ - plasma acceleration

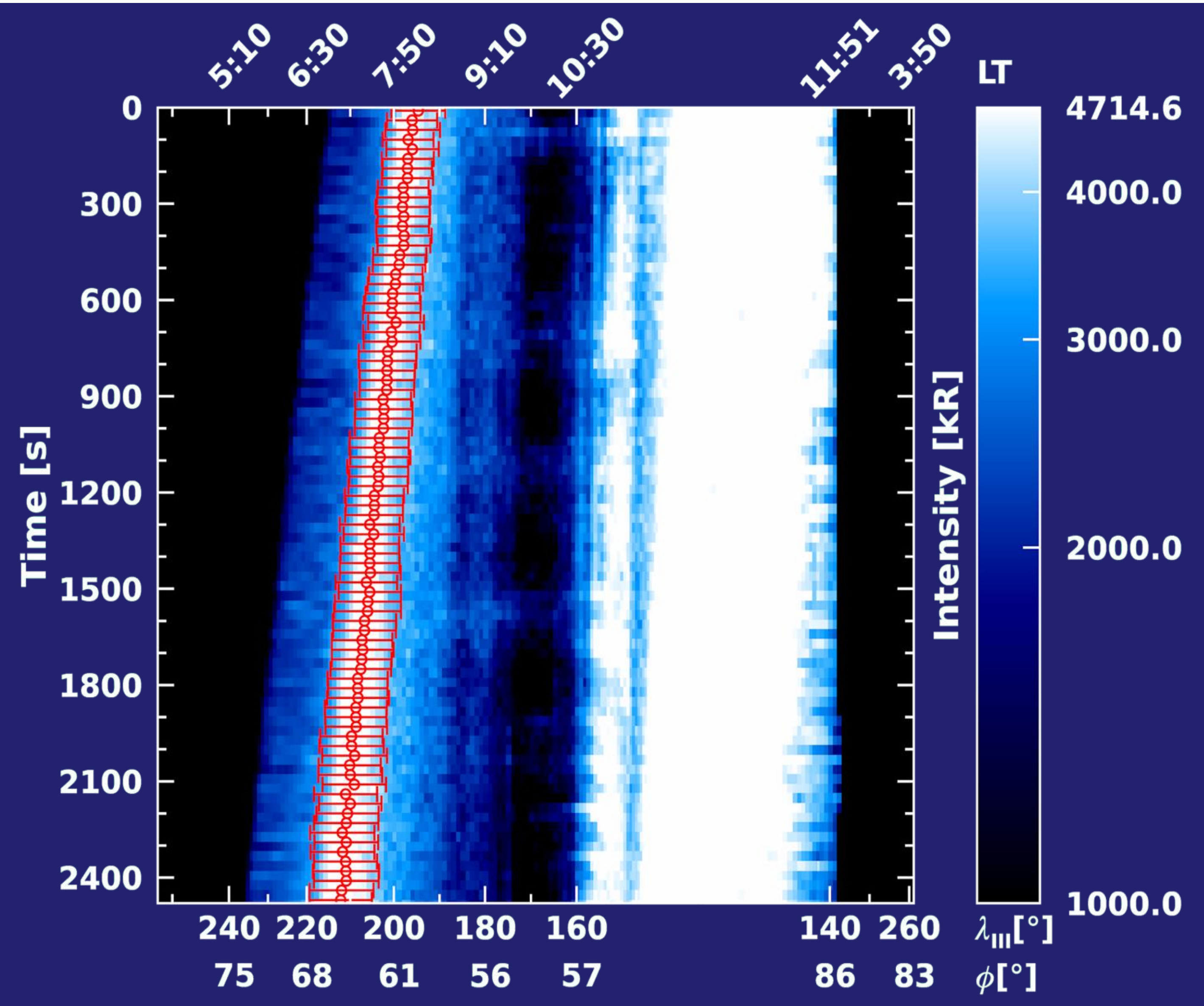
HST AURORAL SURVEY

- Gathered 200+ cumulative hours of HST exposure
- Auroral intensity and position have been used extensively
  - Auroral motion is less often measured
  - But, auroral motion is a useful metric
- Developed a way to measure auroral motion precisely and accurately

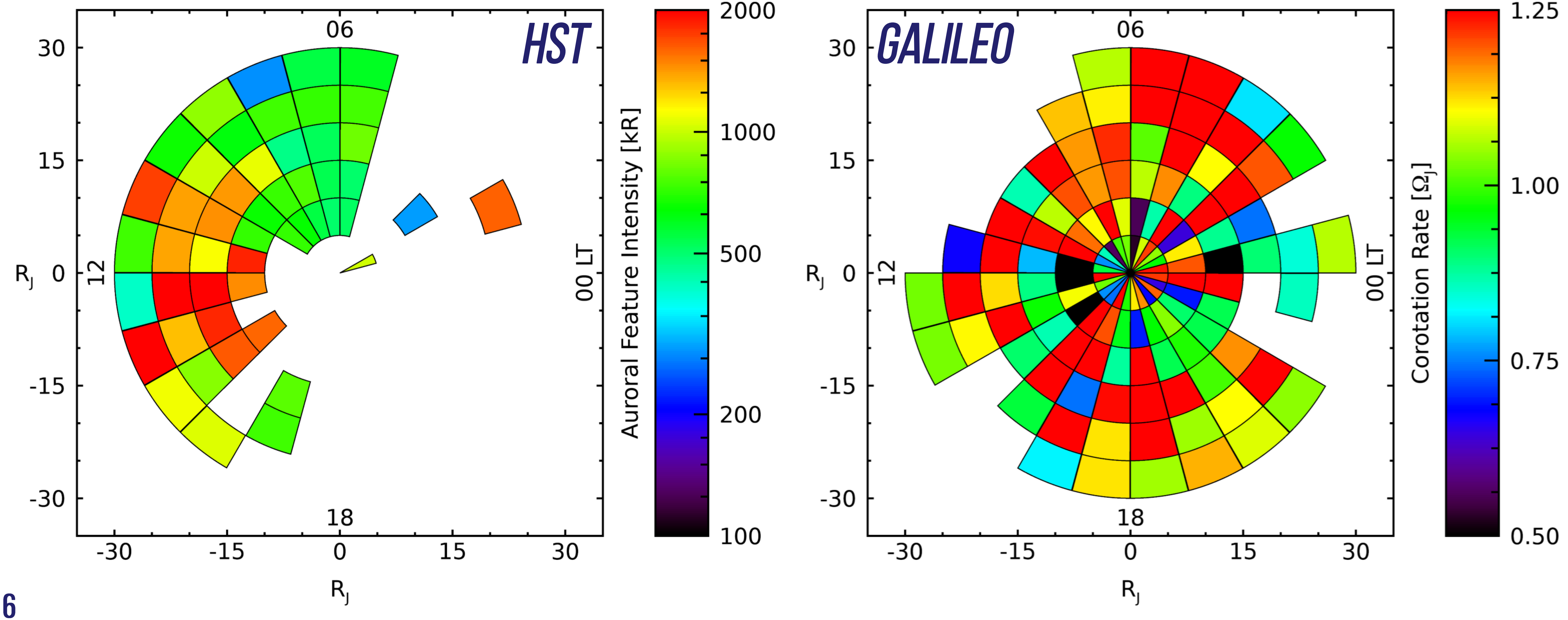
HST GO Program	Start	End	Cumulative Exposure [hours]
10862	Feb. 20, 2007	June 11, 2007	42
14105	May 16, 2016	July 18, 2016	35
14634	Nov. 30, 2016	May 23, 2018	101
15638	Feb. 9, 2019	Sep. 13, 2019	36
Totals			204

FEATURE IDENTIFICATION

- ~800 discrete auroral features detected
- Discrete features identified as:
  - Local brightness maxima 10+% brighter than neighboring points within the same exposure
  - Maxima clustered based on hierarchical density clustering (DBSCAN)
  - Resulting clusters required to span at least 50% of the exposure

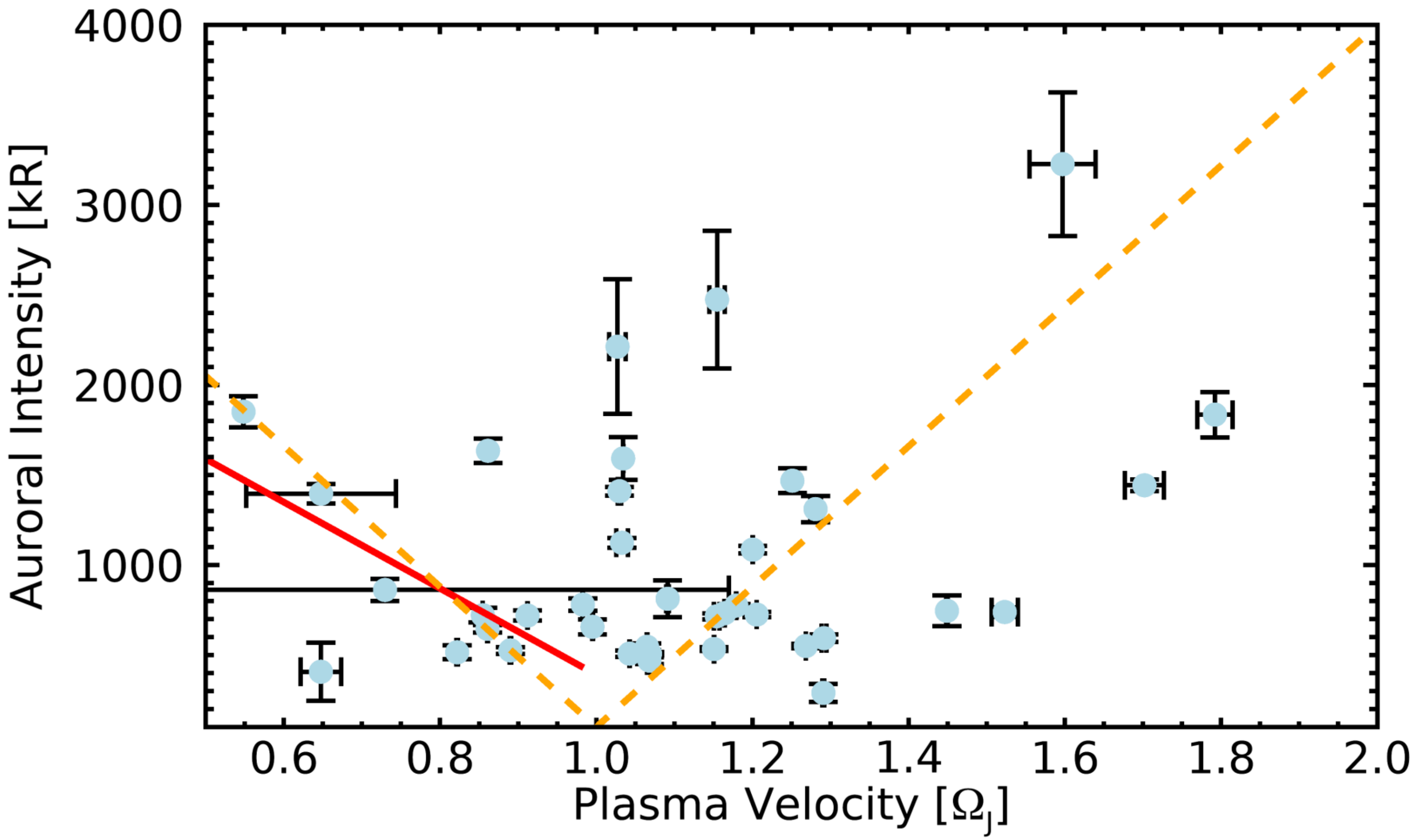


AURORAL INTENSITY VS. PLASMA VELOCITY

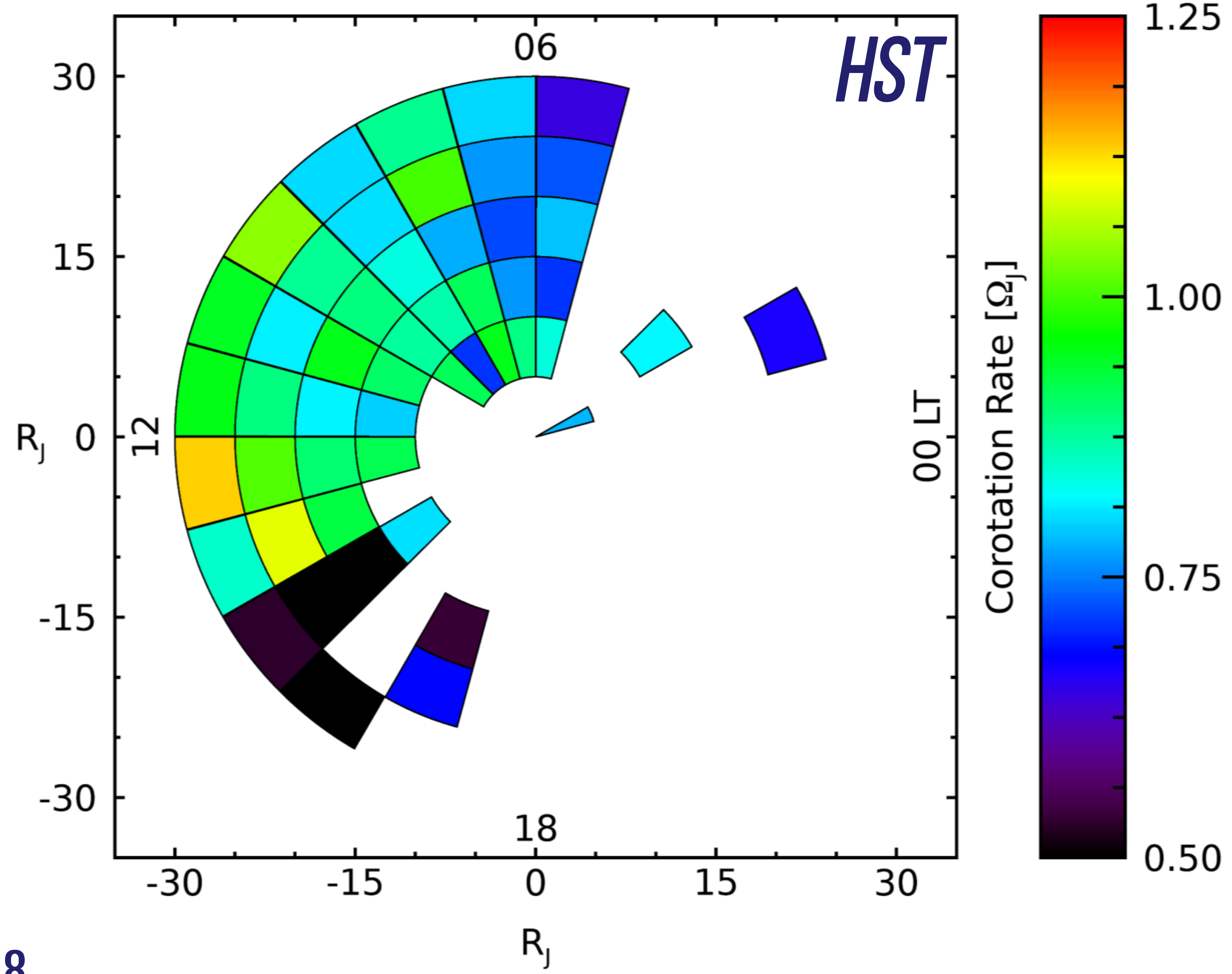


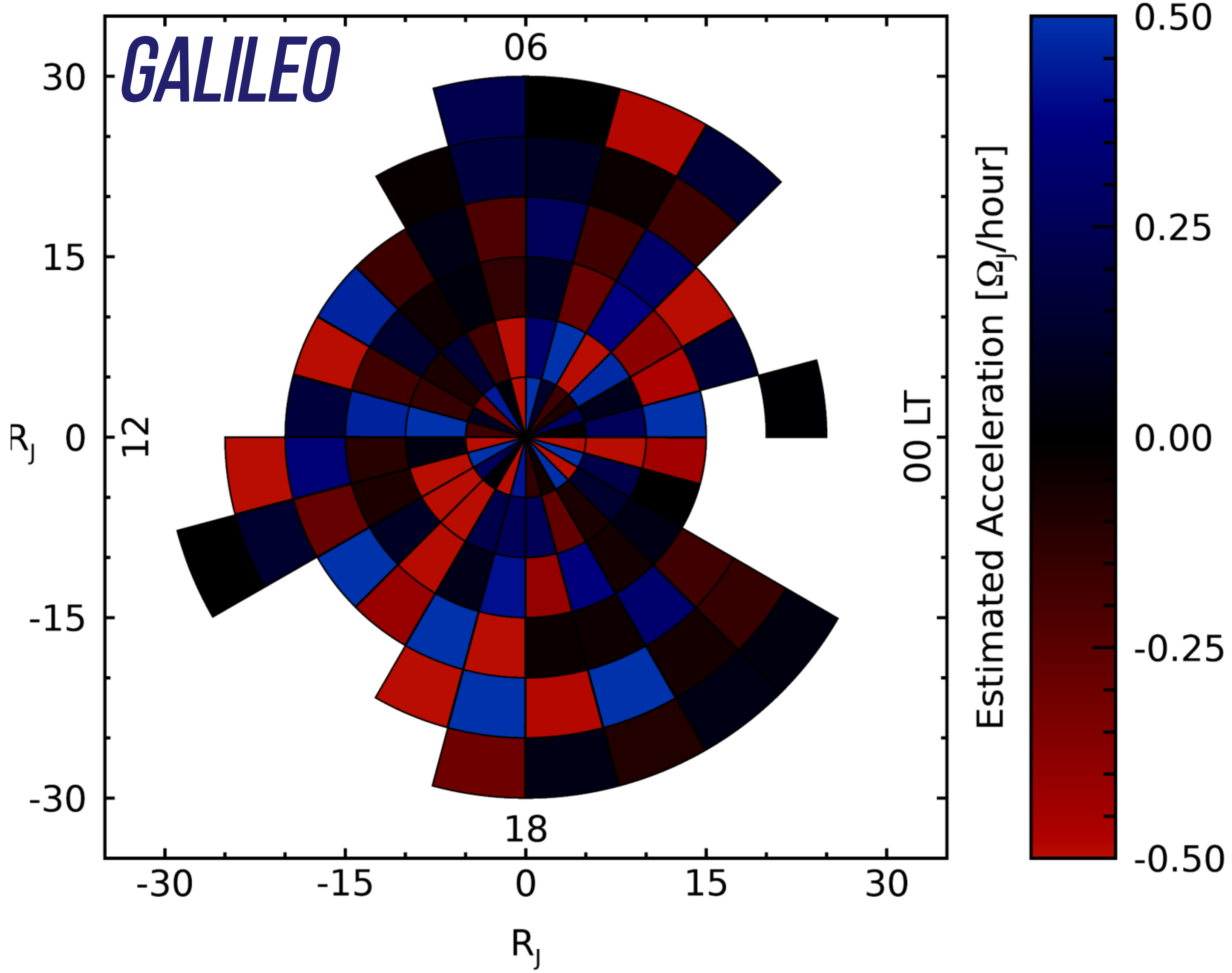
HST AURORAL INTENSITY VS. GALILEO PLASMA VELOCITY

- Auroral intensity $\propto$ negative plasma velocity
  - $I_{||} \propto (|\Omega_J - \omega|)$ 1:1 in orange
  - Measured fit in red
- Measurements generally consistent with expectations
  - Spread may be due to Σ_P^* or F_e, or non-FAC effects



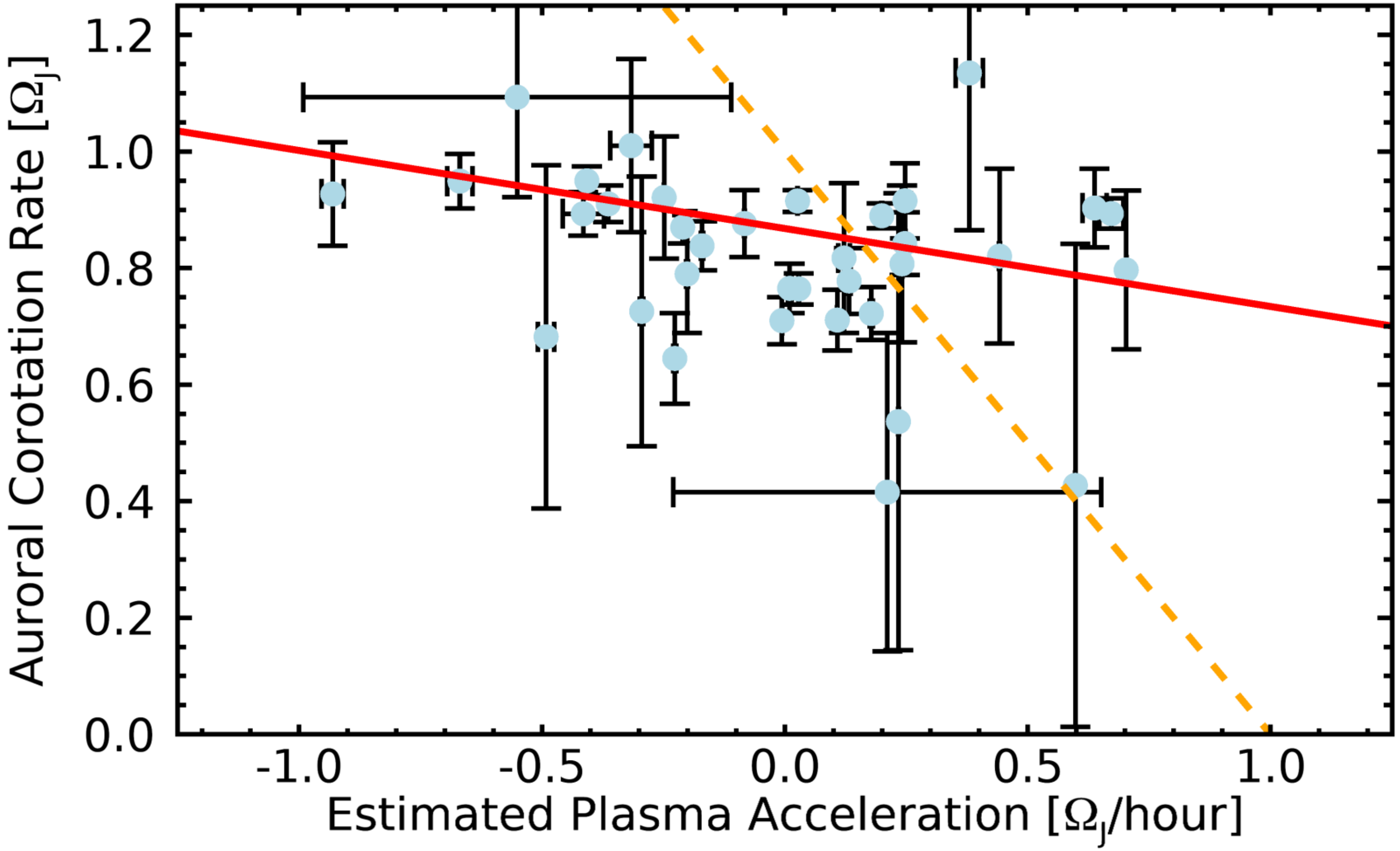
AURORAL MOTION VS. PLASMA ACCELERATION





HST AURORAL MOTION VS. GALILEO PLASMA ACCELERATION

- Auroral motion ∝ negative plasma acceleration
  - $\frac{d}{dt} I_{||} \propto \frac{d}{dt}(\Omega_J - \omega)$ 1:1 in orange
  - Measured fit in red
- Recover the negative proportionality



CONCLUSIONS

- Measurement of auroral velocities to better precision and for more features allows useful new statistics to be looked at
- Initial results comparing HST aurorae statistics and Galileo in-situ statistics are generally consistent with corotation-enforcement theory
  - Auroral intensity ∝ - plasma velocity $\left(I_{||} \propto (\Omega_J - \omega)\right)$
  - Auroral velocity ∝ - plasma acceleration $\left(\frac{d}{dt} I_{||} \propto \frac{d}{dt}(\Omega_J - \omega)\right)$
  - Many outliers
- Planned addition of *Juno* JADE data will drastically enhance plasma statistics in the dawn-midnight sectors
  - Aim is to increase resolution enough to find where the data matches corotation-enforcement theory and where other drivers dominate

THANK YOU

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