Supporting Information for "Alternating North-South Brightness Ratio of Ganymede's Auroral Ovals: Hubble Space Telescope Observations Around Juno's PJ34 Flyby"

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Introduction

The supporting information supplied here provides additional text, one figure and two tables to illustrate in more detail observations and statements made in the main manuscript.

Text S1. The essential physics in the calculation of UV emissions from an atmosphere/exosphere of O and O_2 including electron impact, solar resonance scattering, and solar surface reflection have been discussed in Hall, Strobel, Feldman, McGrath, and Weaver (1995). The ratio of airglow/auroral emission rates for OI 1356/OI 1304 exceed 1.3 on Ganymede (Hall et al., 1998) and are diagnostic that OI 1356 is mostly due to dissociative electron impact excitation of O_2. Our calculations were performed with the best available measured O_2 emission cross sections from Kanik et al. (2003). With these O_2 cross sections the emission ratio of OI 1356 /OI 1304 exceeds 2 over the energy range of these measurements. Performing a comparable calculation for the same emission ratio for electron impact on O atoms yields a ratio that does not exceed 0.4. The measured O_2 emission cross sections were extrapolated with the Bethe-Oppenheimer expression $\sigma 1356(\mathrm{E}) = 4.05 \times 10^{-19}\ \mathrm{E}^{-1} \ln(44\ \mathrm{E})\ \mathrm{cm}^2$, for E in keV above >0.6 keV. Based on Hall et al. (1998), we adopt an O_2 radial column density of $3 \times 10^{14}\ \mathrm{cm}^{-2}$, which implies that the exobase is near the surface of Ganymede.

These calculations with updated O_2 cross sections are displayed in Figure S1. They confirm the previous results in Figure 3 of Eviatar et al. (2001) up to approximately 300 eV and replace the intensities predicted for electrons accelerated into the keV energy range due to the extrapolated cross sections based on the Bethe-Oppenheimer approximation.

Text S2. The error bars in Figures 3 and 4 are calculated based on the counts provided in the flt-files. Each data point in Figure 3a and Figure 4 is calculated based on the counts within the respected exposures and the considered area on Ganymede. The total signal $S = A + R + B$ within the specified areas of Ganymede is composed of counts from the auroral emission A, counts due to reflected light on the surface of Ganymede R and counts due to background noise B of the detector and the sky. The signal to noise SNR in the Poisson distributed photon fluxes is then given by $SNR = (S - R - B)/(S + R + B)^{1/2}$. The error bars on the ratio of signals in Figure 3b is calculated based on standard error propagation (Bevington & Robinson, 2003).

References

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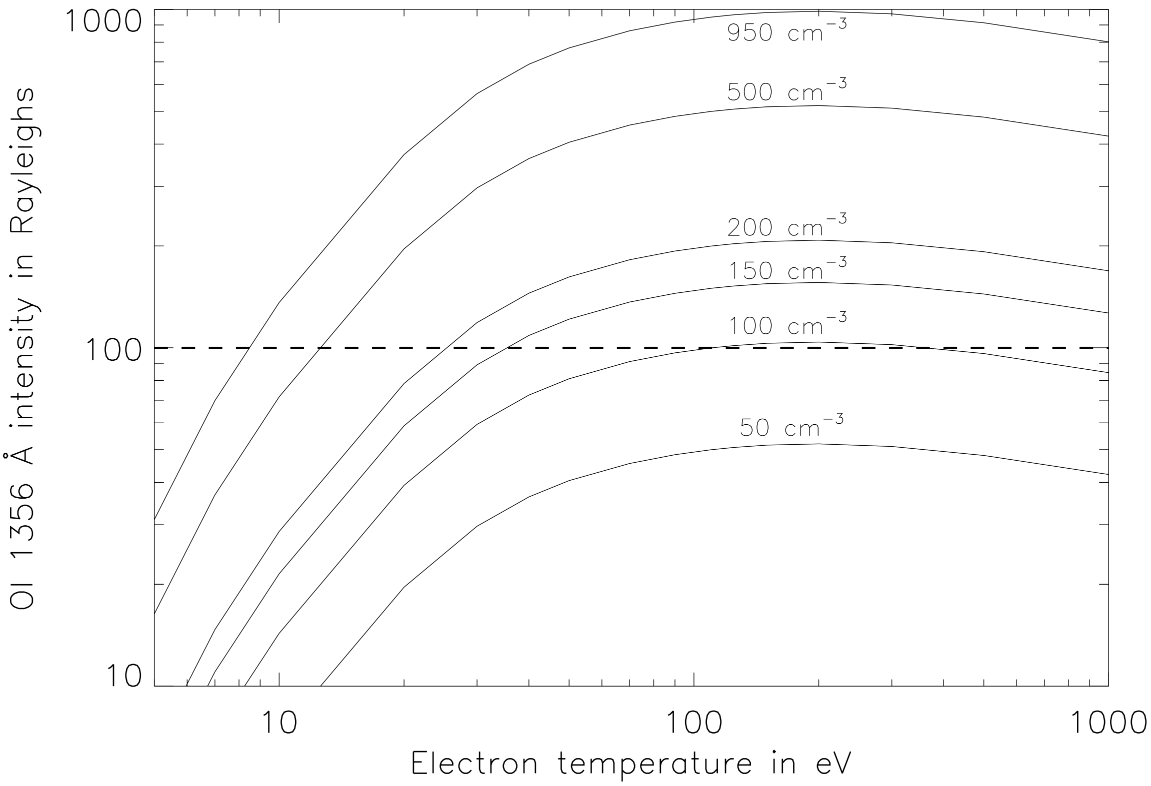

Figure S1. Intensity of OI 1356 Å emission as a function of the electron temperature in Ganymede's ionosphere/atmosphere for various electron densities.

Table S1. Exposure details of HST/STIS observations of Ganymede in support of the Juno flyby on 2021-06-07 (ID: 16499). Juno's closest approach to Ganymede occurred at 17:35 UTC including the light travel time of 39 min to Earth. Orbit 3 of visit 1 and orbit 1 of visit 2 were split up into two exposures each for technical reasons. [a]: UTC at exposure start (light travel time included), [b]: magnetic latitude, [c]: Disk averaged auroral brightness for OI 1356 Å including limb emission up to 200 km, normalized to πR_G^2, for complete HST orbits.

Visit #	Orbit #	Exp #	Root name	Obs. Time[a] hh-mm-ss	Exp. Time s	Ψ_m [b] degree	brightness[c] R
1	1	1	oejj01010	00:54:04	1631	-3.5	132.8 ±4.0
1	2	2	oejj01020	02:29:29	2291	4.7	66.4 ±2.5
1	3	3	oejj01030	03:43:16	1000	9.3	52.8 ±2.2
1	3	4	oejj01040	04:04:38	1076	9.5	
2	1	5	oejj02010	19:44:20	866	-9.5	74.3 ±2.7
2	1	6	oejj02020	20:01:06	800	-9.5	
2	2	7	oejj2A010	21:32:56	1514	-5.5	89.9 ±3.5
2	3	8	oejj2A020	23:08:23	2331	2.5	78.3 ±2.6

Table S2. Statistical properties of 100s sub-exposures of all 6 HST orbits, $\bar{b}$ is the average brightness during each orbit, $\sigma_{sub-exp}$ is the standard deviation of the brightness variability of the sub-exposures during each orbit, and $\bar{\sigma}_{indiv}$ is the average over the individual brightness uncertainties in each sub-exposure based on count statistics, r is the ratio of the brightness variability within sub-exposures to averaged one-sigma brightness uncertainty of individual sub-exposures, i.e., $r = \sigma_{\mathrm{sub-exp}}/\bar{\sigma}_{\mathrm{indiv}}$. A value of $r < 1$ indicates that the variability could be consistent with statistical noise, only.

Visit #	Orbit #	Hemisphere	$\bar{b}$ R	$\sigma_{\mathrm{sub-exp}}$ R	$\bar{\sigma}_{\mathrm{indiv}}$ R	$r = \sigma_{\mathrm{sub-exp}}/\bar{\sigma}_{\mathrm{indiv}}$
1	1	North	231.1	39.7	47.3	0.84
1	1	South	148.0	39.1	35.5	1.10
1	2	North	42.7	32.7	30.3	1.08
1	2	South	108.1	21.5	30.7	0.70
1	3	North	58.3	27.6	31.7	0.87
1	3	South	65.5	26.5	26.3	1.01
2	1	North	99.7	35.1	37.4	0.94
2	1	South	64.0	28.9	23.4	1.24
2	2	North	118.1	38.1	41.1	0.92
2	2	South	92.4	28.4	29.3	0.97
2	3	North	54.6	30.9	36.5	0.85
2	3	South	121.2	32.9	34.6	0.95
average		North		34.0	37.4	0.91
average		South		29.5	30.	0.99