MONTE CARLO MODELING OF IO'S [OI] AURORA IN ECLIPSE. C. H. Moore, D. B. Goldstein, P. L. Varghese, L. M. Trafton, and K. Stapelfeldt*, *The University of Texas at Austin, TX 78712*, chris@cfdlab.ae.utexas.edu, **Jet Propulsion Labs.*

Introduction: Io generates an aurora with different features from Earth's aurora. For example, on Io the 630 nm [OI] aurora is concentrated around the equator whereas on Earth the aurora is mainly around the poles. Observations of Io just after entering Jupiter's shadow by Trauger *et al.* [1] and Retherford *et al.* [2] showed several bright regions of [OI] 630 nm emission. Several features of the aurora should be noted: an equatorial band located along the Jovian magnetic equatorial plane, a limb glow near each pole, a bright spot in the plasma wake which peaks ~150 km above Io's limb and can be tilted relative to Io's equator, and the lack of a bright spot upstream. In the present work, the atmospheric interaction with electrons from the Jovian plasma torus is simulated via 3D direct Monte Carlo simulation. The behavior of the auroral features is expected to provide insight into the torus interaction with Io's atmosphere. Here we will examine the main cause of the wake spot's tilt relative to Io's geodetic equator.

Model: The computational domain is a 6000 km cube centered on Io. The simulation is divided into two routines: Excitation in which the electrons move and occasionally collide with the neutral atmosphere, and Emission in which excited oxygen (produced by electron-oxygen collisions) moves and eventually emits or is collisionally quenched. Further details of the model may be found in our previous LPSC abstract [3]. Several improvements are described briefly below, for more details see our forthcoming Icarus paper [4]

First, the pre-computed neutral atmosphere used in our simulation has been improved in several ways. The previous atmosphere used only the dayside profiles of Wong & Smyth [5] and our simulated nightside plumes [6]. Both dayside and nightside plumes and atmospheric profiles are now used. Also, the plumes have been recomputed with an input plasma energy flux of 5 erg/s/cm^2 and include an O concentration of only 0.01%. Currently, the atmosphere includes density profiles for SO_2, O, SO, and O_2. The last two species are only included in the Emission subroutine; electron cross sections have not yet been added for those species. In addition, results are only be shown for the Wong & Smyth [5] atmosphere profiles, though Smyth & Wong's [7] results have also been used in simulations. Finally, the validity of using Wong and Smyth's [5] atmosphere in eclipse has been investigated and is the subject of our other LPSC abstract [8].

Variable timesteps based on the local number density are now used in both the Excitation and Emission routines. This greatly improved both the accuracy of the simulation in the lower atmosphere and the computational efficiency. Also, we no longer neglect the electron's drift velocity; now the electron's motion includes Combi's [9] (small) pre-computed bulk plasma velocity around Io.

Furthermore, we approximately account for the electron flux-tube depletion across Io by expanding on Retherford's use of the difference in timescales for an electron to drift across Io (~526 sec) versus the time it spends oscillating in the plasma torus (~120-355 sec) [2]. The northern and southern flux tubes in general undergo different amounts of depletion because Io's latitude in the torus varies and the atmosphere is different in the northern and southern hemispheres. Hence, for a constant atmosphere, the north/south ratio of flux tube depletion varies as Io moves latitudinally in the plasma torus.

The flux tube depletion is modeled by determining how many times a representative thermal electron in the flux tube would have to back-scatter off of Io's atmosphere as the flux tube crosses Io in order to reach the wake region (Figure 2). Note that the flux tube is depleted as it crosses Io due to electrons which do not back-scatter, since they are lost (mainly) to Io's surface. Shown in Figure 2, an electron traveling on the north side of Io will have to scatter off of the atmosphere ~4 times (compared to ~once for the south) in order to reach the wake. By inserting many electrons into a given cell and counting how many returned back out of the domain, we computed the fraction of electrons scattered as a function of location. This fraction is then used to approximate the flux tube depletion across Io. When Io is in the extreme north (south) of the plasma torus, the different number of required scattering events in each hemisphere leads to a greater number flux of electrons reaching the wake from the south (north) versus from the north (south).

Results: Figure 3 shows the simulated [OI] line of sight emission contours of Io in eclipse at its low (southern-most) latitude in the plasma torus. Note in Figure 3 that the wake spot location is tilted relative to Io by approximately the same amount as observed in Figure 1 and that the magnitude of the wake emission is of the same order. However, the calculated peak intensity in the wake (~4.5 kR) is ~2 times smaller than observed, the peak intensity occurs at a lower altitude and is not as extended, there is no bright equatorial band, and the ratio of downstream to upstream brightness is ~1.5 instead of ~4 as observed. The discrepancy (between observation and simulation) in absolute wake brightness is most likely due to the lack of a direct SO_2 and SO dissociative-[OI] excitation mechanism in the model. The extent of the wake spot is incorrect mostly because the atmospheric profiles at high altitudes are incorrect; the Wong & Smyth [4] profiles used are simulated via solution of continuum equations which do not apply in Io's upper atmosphere. The error in the downstream/upstream brightness ratio results from several sources: the strength of Io's magnetic field perturbation, the electrons' initial pitch distribution, and the approximate flux tube depletion model used. If the flux tube depletion is modeled such that Io is located at high latitudes in the torus, then the wake spot is found to shift south on Io; however, the upstream spot does not move since the flux tubes are not depleted on the upstream side of Io. Further results with Io located at various latitudes in the plasma torus will be shown during the presentation.

If Smyth & Wong's [7] more recent atmospheric profiles are used, then the overall intensity becomes ~3 times higher than in Figure 3 because of the overall increase in O. However, the morphology of the emission features remains essentially the same. If the flux tube depletion is modeled such that Io is located in the

Conclusions: Several improvements to our auroral simulation code have been made including modeling the flux tube depletion across Io. We find that it is this flux tube depletion that controls the latitude of the wake spot. Discrepancies with observations still exist and are most likely due to the model's lack of direct dissociative-[OI] excitation mechanism, the inadequacy of the atmosphere profiles used, and the approximate model of the flux tube depletion. Both a better atmospheric model and a better model for the flux tube depletion is under development to improve the simulation. Results will be shown that the periodic tilt of the wake spot arises from the asymmetric depletion resulting from the different north/south timescales for electrons to travel between Io and the plasma torus edge.

References: [1] Trauger, J.T., et al. (1977) AAS-DPS abstract 1997DPS29.1802T. [2] Retherford K.D. (2002) PhD dissertation, John Hopkins U. [3] Moore, C.M., et al. (2003) LPSC XXXV, Abs. #1983. [4] Moore C.M., et al., Modeling of Io's [OI] Auroral Emissions in Eclipse, 2006. [5] Wong, M.C. and Smyth W.H. (2000) *Icarus* **146**, 60-74. [6] Zhang, J., et al. (2003) *Icarus* **163**, 182-197. [7] Smyth W.H. and Wong M.C. (2004) *Icarus* **171**, 171-182. [8] Moore, C.M. et al. (2005) LPSC XXXVII. [9] Combi, M.R., et al., *JGR* **103**, 9071-9081.

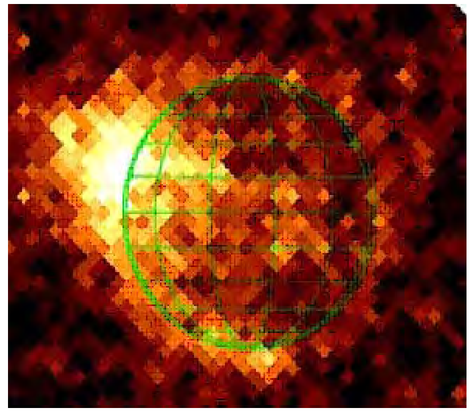

Figure 1: [OI] 630nm emission from Io in Eclipse by Trauger *et al*. [1] with WFPC2 in May 1997.

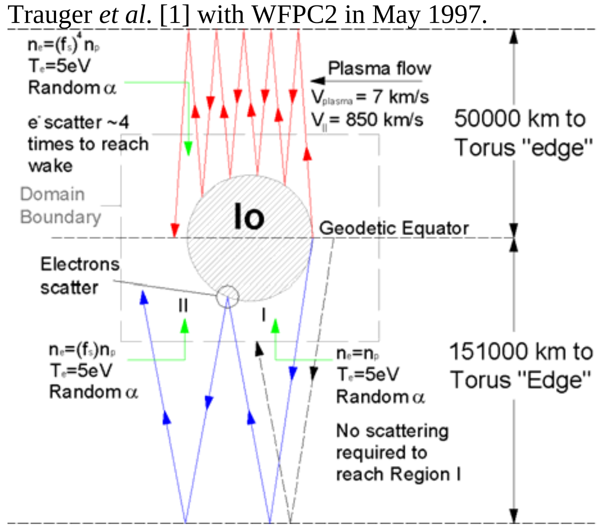

Figure 2: Schematic of plasma flow past Io at its maximum northern latitude in the torus. The red line is the path of an electron just missing Io upstream heading north and then, while convecting past Io, traveling between the torus edge and Io. Each time it reaches Io, it either back-scatters off the atmosphere or is lost.

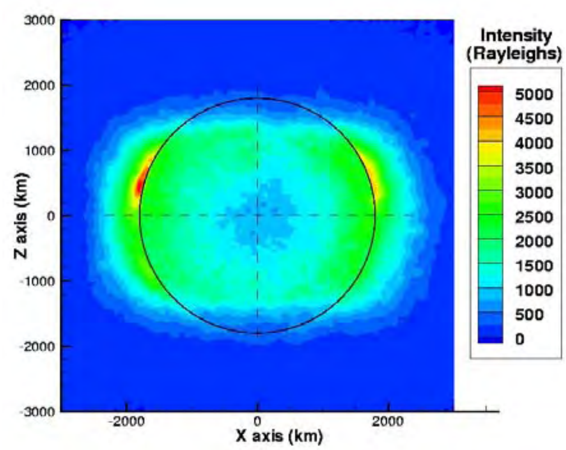

Figure 3: Emission contours for Io at its southern most latitude in the plasma torus.