

# F684 2001 Fall Meeting Planetary Sciences

P11A MC: 309 Monday 0830h

Galileo's Polar Io Flybys:  
Magnetospheric and Geologic  
Observations I (joint with SA, SM)

Presiding: E Turtle, University of  
Arizona; K Khurana, University of  
California at Los Angeles

P11A-01 0830h INVITED

Magnetic Signature of a Polar Pass Over  
Io

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On August 6, 2001, Galileo flew by Io on a low altitude polar orbit, one well suited for determining whether the moon has an internally generated magnetic field. At the time of submission of this abstract, only very low temporal resolution data samples have been received on the ground. Close to Io, the preliminary data appear to exclude internal fields with surface field strengths greater than about 200 nT. Higher resolution data to be returned in August-September 2001 will more accurately constrain this estimate. Field perturbations extending far from Io are consistent with expectations for interaction with an extended cloud of pickup ions. Ion cyclotron wave power in the full resolution data will give information on the distribution of and composition of these pickup ions. Comparisons with previous passes at different latitudes, local times, and positions relative to the flowing torus plasma will be of particular interest. The magnetic signature in the wake of the flow is much weaker on the I31 pass than it was on the lower latitude J0 pass in December of 1995 and we will discuss possible reasons for the differences.

P11A-02 0845h INVITED

Over Io's Poles: Energetic Particle  
Results

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The Galileo satellite flew over the polar cap of Jupiter's moon Io on August 5, 2001. Closest approach was approximately 200 km. Data was recorded throughout the encounter and will be transmitted to Earth over the next several weeks. An additional polar encounter is planned on 14 October 2001. Energetic particle measurements on previous low latitude encounters have shown 1) the existence of intense bi-directional electron beams along field lines in Io's wake; 2) the concurrent existence on the wake field lines of a trapped electron distribution; 3) an electron pitch angle distribution evolution that is consistent with the adiabatic response of the ambient Jovian electrons to the changing magnetic and electric field conditions throughout the encounter; 4) the existence of a region near the moon that is inaccessible to the adiabatically transported electron population; 5) evidence that the electron beams observed in the wake, while not directly responsible for the Io footprint aurora, do comprise a downward current that is an integral part of the electric circuit between Io and Jupiter. We will present the polar cap results and discuss their impact on these earlier conclusions.

P11A-03 0900h

An Overview of Galileo Plasma Wave  
Observations During the I31 and I32  
Flybys of Io

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An overview is given of results from the Galileo plasma wave instrument during the I31 and I32 flybys of Io, which occurred on August 6, 2001 and October 15, 2001, respectively. The I31 flyby passed over the north pole of Io at a closest approach altitude of 194 km, and the I32 flyby passed over the south pole of Io at a closest approach altitude of 180 km. The plasma wave electric field data from the I31 flyby show a very clear upper hybrid emission line during the entire flyby, and a region of intense low frequency electric noise lasting about ten minutes centered on closest approach. The upper hybrid emission line can be used to make very accurate measurements of the electron density. As the spacecraft entered the geometric boundary of the Io magnetic flux tube at about 04:55 UT, the electron density abruptly increased from the ambient level of about  $1.9 \times 10^{13} \text{ cm}^{-3}$  in the Io plasma torus to values ranging from about  $1.2$  to  $1.8 \times 10^{14} \text{ cm}^{-3}$  as it passed over the polar region. As the spacecraft exited the geometric boundary of the Io flux tube, the electron density abruptly decreased down to the pre-existing ambient level in the Io torus. These boundaries coincide within about one minute of the times when the low frequency noise occurs. At the time that this abstract was written no data were available from the I32 flyby.

P11A-04 0915h INVITED

Probing the Mysteries of Io's Ionosphere  
With the Plasma Instrumentation on  
the Galileo Spacecraft

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At the time of writing this abstract the measurements during the close flyby of Jupiter's moon Io had been just acquired with the Galileo recorder for subsequent transmission to Earth at much lesser telemetry rates. This flyby near Io's northern pole on August 6, 2001 and a future flyby near the southern pole on the following October 16 will provide the plasma measurements for this presentation. These in-situ observations of Io are expected to provide further insight into the nature of its ionosphere and the accompanying currents and charged particle acceleration. Surprises can be expected from these flybys. For example, the flyby with closest approach at 208 km on February 22, 2000 provided a direct passage through the thermal ions at the top of the ionosphere. A cool plasma was encountered with temperatures of about 2300 K, and in the range of the hotter temperatures for some volcanic plumes as recorded remotely with other Galileo instruments. The observations from the flybys in August and October at closest approaches of 200 km and 181 km, respectively, are eagerly awaited.

P11A-05 0930h

Ion cyclotron waves at Io on orbit I31

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Previous Io flyby passes had been at solar phase angles near noon (I0) near 1045 LT (I24, I25) and near 0900 LT (I27). These passes showed a progression of behavior with the solar phase angle. On I0 the ion cyclotron waves had been peaked very strongly near the SO<sub>2</sub> ion cyclotron frequency inbound when the spacecraft was above the daylight hemisphere of Io but were

very broad in extent. Above the dark side of Io the wave frequency switched to that of SO. On later passes (but at earlier solar phase angles) the wave amplitude was less than on I0 and multiple ion cyclotron waves seen simultaneously in narrow bands. Thus on the I31 pass we expected to observe weak narrow-banded signals. Instead the signals are as strong as on the passes near 1030 LT and they are quite broad in frequency extent. The strength of the waves may be explained by the trajectory of Galileo that remained close to the edge of the co-rotation wake. The broad spectrum of waves suggests the presence of ions from about the mass of sulfuric acid (98) to that of sulfur (32). Over this whole band the waves are left-hand elliptically polarized and propagate at a small angle to the field.

P11A-06 0945h

Energetic Ion Observations at Io

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With the conclusion of the Io-encounter in orbit I32 on October 16, 2001 the Galileo spacecraft will have passed by the moon on 6 separate occasions. During most of these passes the intensities of heavy ions above 4 MeV/nucleon have been measured by the Heavy Ion Counter (HIC). We compare and contrast these data in terms of the geometry of Galileo's trajectories past Io and discuss the results in terms of ion dynamics and losses near the moon.

P11A-07 1000h

Modeling Io's electrodynamic  
interaction with its torus:  
Comparison with recent observations.

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In this paper we present results of a three dimensional two-fluid plasma model that describes the electrodynamic interaction of Io with its plasma torus. Among other things, we discuss how a polar flyby is very well suited to determine whether Io has an internal magnetic field or not. From a polar flyby, we also expect insight into Io's electric current and Alfvén Wing system. The degree of rotation of the Alfvén wings allows to conclude properties of Io's atmosphere. We also look at aspects of the pickup processes, e.g. the total rate and their action on the plasma flow. Depending on the availability of data, we might also discuss how HST observations of the satellites UV emissions is related to the electrodynamic interaction and atmospheric properties.

P11A-08 1015h

MHD Models of Io's Interaction with  
the Plasma Torus: Comparison with  
the Polar Flybys

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The original flyby of the Galileo spacecraft past Io in December, 1995 gave unprecedented observations, but in many ways these measurements raised more questions than they answered. In particular, the

plasma-interaction signature in the magnetic field measurements was consistent with an intrinsic magnetic field at Io, but this was not the only possible explanation for the results. During the I27 flyby (February, 2000), Galileo probed a region on the flanks of Io that was sensitive to differences between the magnetized model of Io and the conducting model of Io. Based on the modeling of the Io interaction for this encounter, it seems unlikely that there is significant intrinsic magnetization at Io. The August, 2001 and October 2001 passes over the poles of Io should either confirm or refute these results. We will present comparisons of MHD model results with data from the new Galileo flybys and assess the likelihood of intrinsic magnetization at Io.  
Research Supported by NASA.

#### P11A-09 1050h INVITED

##### Galileo SSI Images of Io During the I31 and I32 Flybys

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The Galileo spacecraft completed the I31 pass of Io on August 6, 2001 and will encounter Io again on October 16 (I32) and Jan 17, 2002 (I33). All I31 images planned while Galileo was closest to Io were lost because of an electronic problem with the SSI camera related to the intense natural radiation near Jupiter, but new workarounds may result in successful imaging close to Io in I32 and I33. Distant observations of Io were successfully acquired, consisting of high-phase (134 degrees) images and two low-phase color sets. As of the abstract due date we have seen only preliminary versions (at high compression) of the high-phase images; they reveal a new bright plume near 37 N, 110-140 W, where no plume has been previously detected. The main purpose of this observation was to attempt to see the giant but faint N. Polar plume of Tvashtar, which was active (400 km high) during the joint Cassini/Galileo flyby in Dec. 2000. Galileo would have flown through this plume if it were in a similar state during I31. Low-compression versions of the I31 images may yet reveal this faint plume. The low-phase color sets of I31 will show us how the bright red plume deposit of Tvashtar may have changed. They could also reveal other surface changes, perhaps even a new plume deposit around Surt (45.5N, 338W), where an intense and high-temperature infrared brightening was observed on Feb. 22, 2001 by de Pater et al. with Keck II (IAU Circular 7588). I32 is a south polar pass with many excellent Io imaging opportunities. If the camera behaves, we'll show the first framelets at Fall AGU.

#### P11A-10 1105h INVITED

##### Io's Volcanic Activity: New Results from Galileo's Near-Infrared Mapping Spectrometer

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The Near-Infrared Mapping Spectrometer (NIMS) on Galileo observed Io during the spacecraft's latest two encounters with this moon, on August 2001 (I31) and October 2001 (I32). The spectral range of NIMS (0.7 to 5.2 microns) allows the instrument to map the thermal emission from Io's many volcanic regions, and the surface distribution of SO<sub>2</sub> and of a yet-identified compound that absorbs near 1 micron. Band ratio and thermal maps were obtained for several volcanically active regions and results compared with those from observations obtained in the earlier fly-bys of October 1999 (I24), November 1999 (I25) and February 2000 (I27). The latest observations show significant changes at the Tvashtar volcanic region, which was first observed as active during I25. The locations active during I25 and I27 still show thermal emission, most likely from cooling flows, but renewed activity took place at a third location. Other areas in this chain of calderas also show thermal emission, indicating that the region is a particularly active one on Io. Tvashtar is located at about 63 degrees north latitude and may be one of the

few active areas at high latitudes. A regional observation at 22-34 km/pixel of Io's disk from north to south polar regions obtained in I31 indicates that volcanic activity may be relatively rare at high latitudes compared to the equatorial and mid-latitudes. This confirms previous suggestions about the global distribution of hot spots on Io from NIMS observations at lower spatial resolution (of the order of 200-400 km/pixel), and also from imaging data. We will present results on the global distribution of volcanic activity, and on individual volcanic centers targeted during the fly-by, including the Amirani/Maui region, Prometheus, and Pele. Prometheus and Amirani show similar styles of activity: long lava flows that, in the case of Prometheus, feed a persistent plume. The plume reported by Voyager (but not Galileo) at Maui may have been the result of the interaction of a lava flow that runs from Amirani toward Maui, but which is no longer active. Small-scale changes at several active volcanic centers are assessed by comparing the latest observations (2001) with those obtained in 1999 and 2000. We also report results on regions not previously observed at high spatial resolution by NIMS, including Gish Bar and Isum. High spatial resolution observations obtained during the fly-bys show that the structure of these hot spots is more complex than thought from distant observations and that hot spots are often made up of more than one volcanic center. Galileo observations have shown that Io's surface is dotted with many active volcanic centers, concentrated at low and mid-latitudes, separated by plains where SO<sub>2</sub> is being continuously deposited.

#### P11A-11 1120h INVITED

##### Recent Results from Galileo PPR at Io

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The Galileo Photopolarimeter-Radiometer instrument has continued its temperature mapping of Io during I31 (August 2001) and, hopefully, in I32 (November 2001). Highlights of the successful I31 flyby include the first high resolution scan of Loki Patera, an active hotspot, since I27 (February 2001), the first high resolution scan of the high-latitude hotspot Lei-Kung Fluctus, the first nighttime global and regional maps since I27, and the first high resolution daytime global map. Previous global nighttime maps showed Lei-Kung Fluctus to be a large area of elevated temperature unlike the point source signatures of most hotspots. Global and Region resolution temperature maps are also particularly useful in determining Io's heat flow. Daytime temperatures will be used to constrain thermal inertias and thereby remove the passive component to the heat flow. Further, previous global maps did not show the expected decrease in nighttime background temperature with increasing latitude expected for solar heating. The higher resolution scans of high-latitude regions may give insight into the reason for this.

#### P11A-12 1135h

##### Surface Changes on Io: Evolution of a Polar Plume Deposit

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Io's appearance is constantly changing due to the vigorous volcanic activity on the surface of the satellite. Dramatic eruptions of silicate lava and ash accompanied by sprays of sulfur dioxide frosts produce the most obvious and colorful surface changes. More

subtle are the gradual changes that result from fading of existing deposits. Galileo has documented the disappearance of several once-prominent volcanic deposits such as those at Pillan, Surt and Aten, but the mechanisms and time scales for this gradual fading are unknown. They may be caused by burial, erosion or alteration of the older surface materials. Alteration may be very different near the poles of Io than at lower latitudes. The eruption of Tvashtar late last year provides an opportunity to study the evolution of a conspicuous plume deposit near Io's north pole. Tvashtar's enormous red ring rivals that of Pele and is presumed to be similar in composition. It was imaged both by Galileo (during orbit 29) and by Cassini as it flew through the Jupiter system, and is large enough to be resolved by Earth-based telescopes. Galileo recently re-imaged the Tvashtar region during orbit 31. These data were successfully recorded but have not yet been telemetered to Earth at this writing. The new images should enable us to determine how the color and albedo of these distinctive deposits have altered over an 8 month period.

Several smaller changes can be seen in the Galileo images from orbit 29. Pele's red ring continues to be replenished and has nearly buried the dark deposits from Pillan. Nearby Reiden Patera, on the other hand, has darkened noticeably since orbit 24 and sprouted bright red pyroclastic deposits of its own. Another caldera that has darkened is located at 24S, 148W, to the east of Culann. This unnamed volcano was formerly covered with greenish materials during orbit 14. Dark diffuse deposits have appeared along the eastern edge of Amirani since orbit 21. New white and red deposits were also noted near the perennially active plume Prometheus.

Results of Galileo imaging from orbits 29 and 31 will be presented.

#### P11A-13 1150h

##### Evidence for a topographically controlled sulfur dioxide deposit at Chaac caldera, Io

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Sulfur Dioxide is ubiquitous on Io's surface. The presence of SO<sub>2</sub> on Io has been recognized since the early seventies and the NIMS instrument mapped its widespread presence on Io in the nineties, during the Galileo prime mission. This mapping, obtained at resolutions varying from about 150 to 400 km/pixel showed that the strength of the SO<sub>2</sub> absorptions varies considerably across Io's surface. When the relative band strengths are converted surface abundance it becomes evident that there is poor correlation between areas having high visible albedo (white areas) and areas having the highest concentrations of SO<sub>2</sub>. This result was unexpected, since pure SO<sub>2</sub> frost is visibly white, and has been interpreted as evidence that SO<sub>2</sub> often may be co-deposited with other materials.

In contrast, observations obtained in February 2000 (orbit I28) and planned for October 2001 (orbit I32) by the NIMS and SSI instruments near the Chaac region, measure an area that exhibits one of the highest abundances of SO<sub>2</sub> seen to date, and that is visibly very bright. The shape of this area is clearly controlled by topography, suggesting that the SO<sub>2</sub> in the area was not emplaced by deposition. The high visible brightness of the deposit suggests that this SO<sub>2</sub> was not deposited directly from a plume. The shape, color, and high abundance of SO<sub>2</sub> in this deposit suggest that it may have been emplaced by liquid flow. The frequency of occurrence for deposits similar to this could not be estimated from the current Io data set, because the size of the feature, 100 square kilometers, is below the spatial resolution of the available spectral maps of Io. However, NIMS observations planned for orbit I32 (Oct, 2001) will obtain high spatial resolution data both on Chaac and on other calderas that have high albedo at visible wavelengths.

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