# Planetary aurorae and their electrodynamic drivers; solar wind vs. internal processes

#### N. Krupp and the Europlanet N2 Discipline working group on Magnetospheres, Exospheres, Ionospheres

special thanks to Fran Bagenal and Emma Bunce



# Jupiter's magnetosphere



## Jupiter Different types of aurora



Max-Planck





#### **Side View**

Max-Planck-Institut für

~



#### **Side View**



Norbert Krupp et al.

EPSC2006-A-00395









#### **Side View**

EPSC2006-A-00395

Norbert Krupp et al.

Max-Planck-Institut für

## Large-scale current system in the Jovian magnetosphere



After Hill (1979) and Vasyliunas (1983)

- Discovery of a local time asymmetry in the system of azimuthal currents which distend the field lines away from the planet (Bunce and Cowley, 2001a; Khurana, 2001)
- Investigations of field-aligned currents associated with magnetosphere-ionosphere coupling currents found to be ~1µAm-2 (Bunce and Cowley, 2001b; Khurana, 2001)





# **Galileo observations**

defined > Most prominent well and boundary -> change in the electron pitch angle distributions located between 10 and 17 R<sub>1</sub>





Max-Planck-Institut für

# Tracing the magnetic field lines

> Comparing the footprints of the PAD boundary (VIP4 model) with the HST observations



> Good conjugation between the PAD boundary and the secondary oval



EPSC2006-A-00395

# The Precipitation energy flux

#### ≻Considering:

 $\succ$  The precipitation energy flux given by :

 $\varepsilon = \int_{E_{\min}}^{E_{\max}} E \cdot j(E, \gamma) \cdot dE$ 

Measured electron's spectra at the PAD boundary.

> Strong pitch-angle scattering.

➢ Electron's energy :  $E_1 \in [55, 304]$  keV.  $E_2 \in [55, 188]$  keV.



Courtesy of D. Grodent, Univ. Liège

 $\succ$  Sufficient to directly produce the observed auroral emissions of the secondary oval without the need of a field aligned potential drop.



#### **Dynamics in Jupiter's magnetosphere** Energetic Particle Injections & correlation to auroral emissions



HST Image of Jupiter's UV aurora



Mauk et al., 1997; 1999, 2000

#### Extreme "storm-time" dynamics observed in the vicinity of Europa's orbit

Auroral manifestation of near-Europa storm dynamics



EPSC2006-A-00395

EPSC, September 19, 2006, Berlin, Germany

Norbert Krupp et al.

# Dynamics of the Jovian magnetotail



EPSC2006-A-00395

EPSC, September 19, 2006, Berlin, Germany

Norbert Krupp et al.

Max-Planck-Institut fü

## **Jupiter**

#### Aurora and tail disruptive events (Grodent et al., 2004)

	In Situ* Russell et al., Woch et al., Krupp et al.	Auroral Spots
Distance	70-120 Rj	>100 Rj
Local Time	postmidnight	premidnight
Size	~25 Rj	5-50 Rj
Duration	Mins-hours	5 min-1hour
Recurrence	4 hours-3days	1-2 days

Max-Planck-Institut für

#### Jupiter Tail disruption events - numbers



# ~8000 Rj x 0.01 ions/cc = 500 tons per plasmoid

# 1 per day = 0.006 ton/s 1 per hour = 0.15 ton/s



EPSC2006-A-00395

# Saturn's aurora

Saturn's magnetosphere is also believed to be corotation-dominated, like Jupiter's It also has an auroral oval as shown in the HST-STIS images below Is this also due to corotation-enforcement currents?





Planetary aurorae and their electrodynamic drivers; solar wind vs. internal processes

Norbert Krupp et al.

Max-Planck-Institut für

Field-aligned current density in the northern ionosphere calculated from the divergence of the horizontal current - effect of the large-scale flow variation Taken from Cowley and Bunce, 2003



#### Saturn's polar ionospheric flows and their relation

#### to the main auroral oval



EPSC2006-A-00395





model estimates are in good agreement with HST-STIS images of Saturn's auroral oval



EPSC2006-A-00395

Image taken from Cowley et al., 2004 EPSC, September 19, 2006, Berlin, Germany

Norbert Krupp et al.

## Electron beams





- FUV auroral images from HST STIS instrument (Gérard et al., JGR 209, 207, 2004) [no observations of the aurora during the electron beam events]
- ~80 deg latitude feature corresponds to just inside m'pause; others are from much deeper in the magnetosphere.
- Periods of electron counterstreaming map into auroral zone. Beams map well in a statistical sense into the regions of Saturn's aurora.



#### Outer magnetosphere dynamics: aurora and radio emissions show rotational modulation + solar wind control



[Kurth et al., 2005]

#### Europlanet N2 DWG 2 Science Case 1

1 - Objective or science goal:

Solar wind interaction at Jupiter and Saturn including aurorae?

2 - Needed data sets:

Millennium Campaign at Jupiter (Cassini, Galileo, Hubble Space telescope (UV), Chandra X-ray Observatory, X-ray Multi-Mirror, InfraRed Telescope Facility), other ground-based observations

Saturn Hubble campaign 2004 and 2007

**3 - Problem description** 

Modelling of the Solar wind-magnetosphere-ionosphere coupling e.g. reconnection rates, cusp processes and compare it with existing data sets. Variations of particle fluxes, pitch angle distributions, energy spectra, aurora brightness,... as indicators of solar wind influence.

4 - Current solution: the way scientist presently work to select data of interest, to access these data and to process it.

PDS, MAPS KP, direct contact between scientists

#### 5 - What services users expect from an IDIS to work more efficiently

add new data sets (relevant events on the Sun, additional data sets from missions in Earth orbit and in the heliosphere for a given time period), add new global transport and plasma models, add relevant Laboratory measurements

- 6 Other comments
- 7 Key references on science and methodology for this science case Cowley and Bunce, Clarke et al., Crary et al, Hansen et al., Tomas et al.,... experience from Earth magnetosphere,...



Norbert Krupp et al.