The DREAM and ARTEMIS lunar plasma science connection

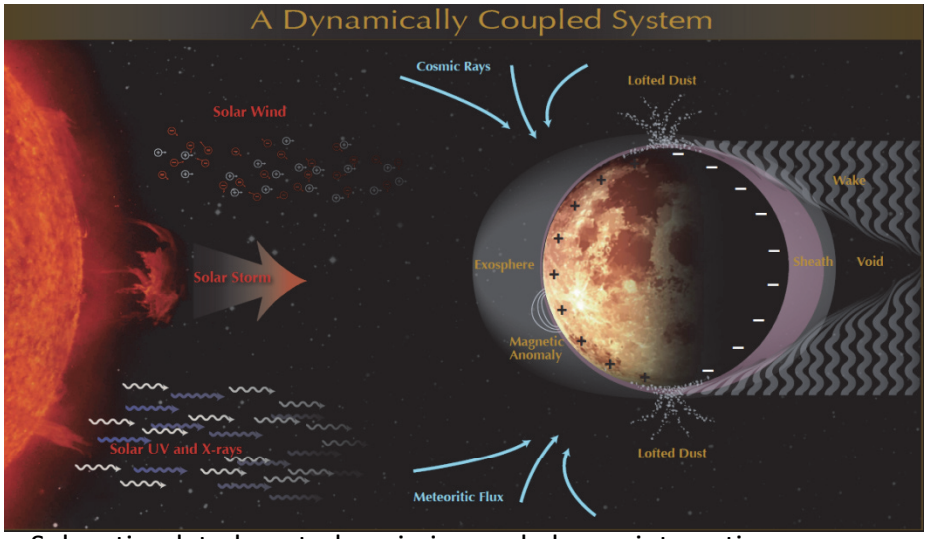
W.M. Farrell, R.M. Killen, G.T. Delory, and the DREAM Lunar Science Institute

THEMIS/ARTEMIS SWG 091411

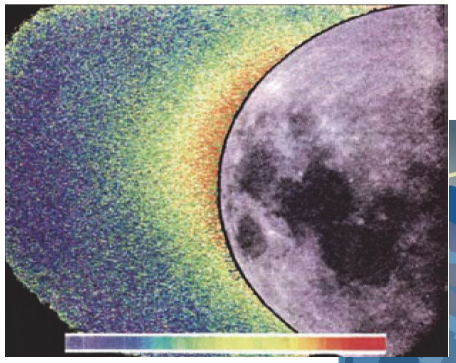
- What is DREAM?
- Stands for: *Dynamic Response of the Environment at the Moon*
- In 2007, NASA's Planetary Division formed a **virtual institute** to pursue dedicated theme-based lunar science topics…analogous to NAI
- In 2008, 7 science teams or 'nodes' were selected via a CAN under LSI central direction
- DREAM is one of these teams picked to examine and advance understanding of solar-lunar connection

DREAM

Dynamic Response of the Environment at the Moon



Solar stimulated neutral emission and plasma interactions



Observations of lunar sodium atmosphere

Astronaut in Shackleton Crater

- "How does the highly-variable solar energy and matter incident at the surface interface affect the dynamics of lunar volatiles, ionosphere, plasma, and dust?"
- Model/data validation team
- Emphasize the dynamics – solar storms and impacts at the Moon
- Provide science support to missions like LADEE, LCROSS, LRO, Kaguya, Lunar Prospector

LSI TEAMs include

The Moon as Cornerstone to the Terrestrial Planets: The Formative Years; principal investigator Carle Pieters, Brown University in Providence, R.I.

'Of'

Impact Processes in the Origin and Evolution of the Moon: New Sample-driven Perspectives; principal investigator David Kring, Lunar and Planetary Institute in Houston

Understanding the Formation and Bombardment History of the Moon; principal investigator William Bottke, Southwest Research Institute in Boulder, Colo.

Dynamic Response of the Environment at the Moon; principal investigator William Farrell, NASA Goddard Space Flight Center in Greenbelt, Md.

'On'

Scientific and Exploration Potential of the Lunar Poles; principal investigator Ben Bussey, Johns Hopkins University Applied Physics Laboratory in Laurel, Md.

NASA Lunar Science Institute: Colorado Center for Lunar Dust and Atmospheric Studies; principal investigator Mihaly Horanyi, University of Colorado in Boulder

Lunar University Node for Astrophysics Research: Exploring the Cosmos from the Moon; principal investigator Jack Burns, University of Colorado in Boulder.

'From'

"How does the highly-variable solar energy and matter incident at the surface interface affect the dynamics of lunar volatiles, ionosphere, plasma, and dust?"

DREAM has four supporting themes that address this overarching question:

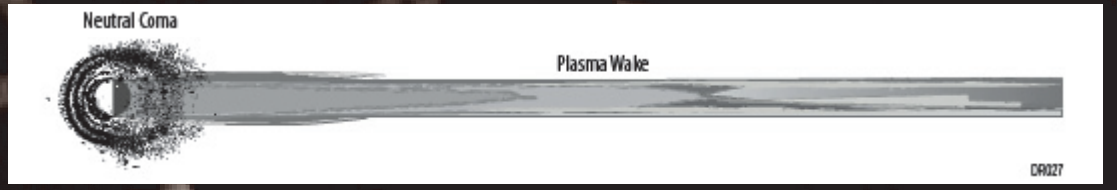
1. Advance understanding of the surface release and loss of the **neutral gas exosphere** over small to large spatial scales and a broad range of driver intensities.

2. Advance understanding of the enveloping **plasma interaction region** over small to large spatial scales and over a broad range of driver intensities.

3. Identify **common links** between the neutral and plasma systems and test these linkages by modeling **extreme environmental events.**

4. **Apply** this new-found environmental knowledge to guide decision-making for future missions, assess the Moon as an observational platform, and aid in human exploration.

DREAMs first model:
Na coma and wake



DREAM Models

CCMC MHD codes of solar wind/CMEs

Monte Carlo Exosphere (Crider/Killen)
Monte Carlo Regolith (Crider/Vondrak)
Ar-40 Monte Carlo Sims (Hodges)
Neutral/surface ejection (Sarantos/Killen)
Exo-ion pickup (Hartle)
Impact Model – LCROSS (Colaprete)
Impact Model – Snowball (Crider)

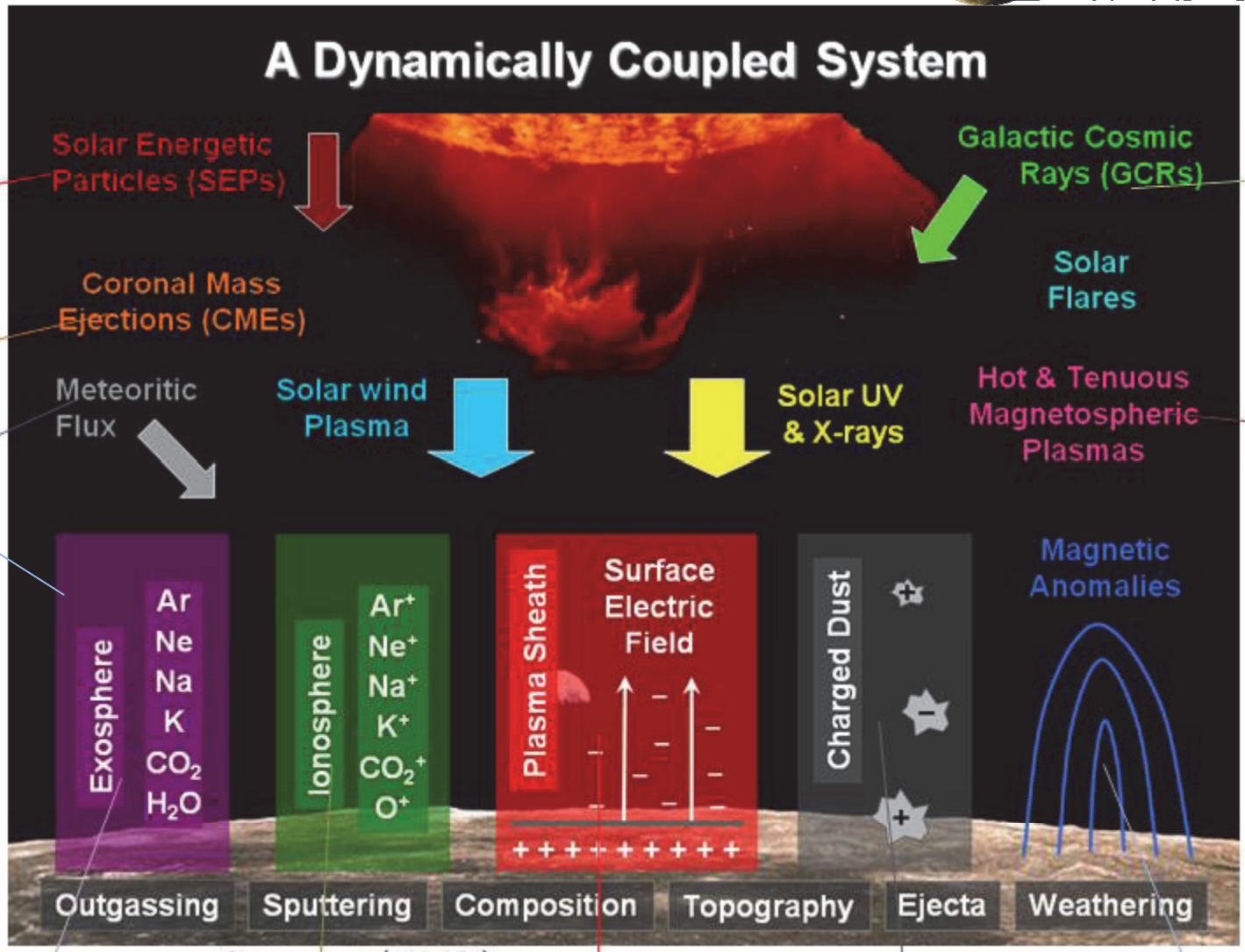
Hybrid/Kinetic plasma sims (Krauss-Varben)
Kinetic wake sim (Farrell)
Equivalent circuit model (Farrell/Jackson)
Surface charging model (Stubbs)
Dust Fountain model (Stubbs)
Mie scattering model (Glenar)

DREAM Validation Sets

Direct (public domain):
WIND (Lin/Bale)
GEOTAIL (Peterson)
SIDE ALSEP (Collier)
LP MAG/ER (Lin)
Apollo 15/16 subsat plasma

Indirect (access via co-i):
ARTEMIS (many)
Kaguya PACE (Saito, Elphic)
LRO (Vondrak, Keller, Stubbs, Spence)
LCROSS (Colaprete)
LADEE (Colaprete, Horanyi)
Constellation (Hyatt, Farrell, Dube)

DREAM



Lin (UCB)

Bale (UCB)

Colaprete (ARC)

Spence (BU)

Patterson (HU)

Crider (APL)
Killen (UMD)
Hodges (UTD)
Vondrak (GSFC)

Sarantos (UMD)
Hartle (GSFC)
Elphic (ARC)
Collier (GSFC)

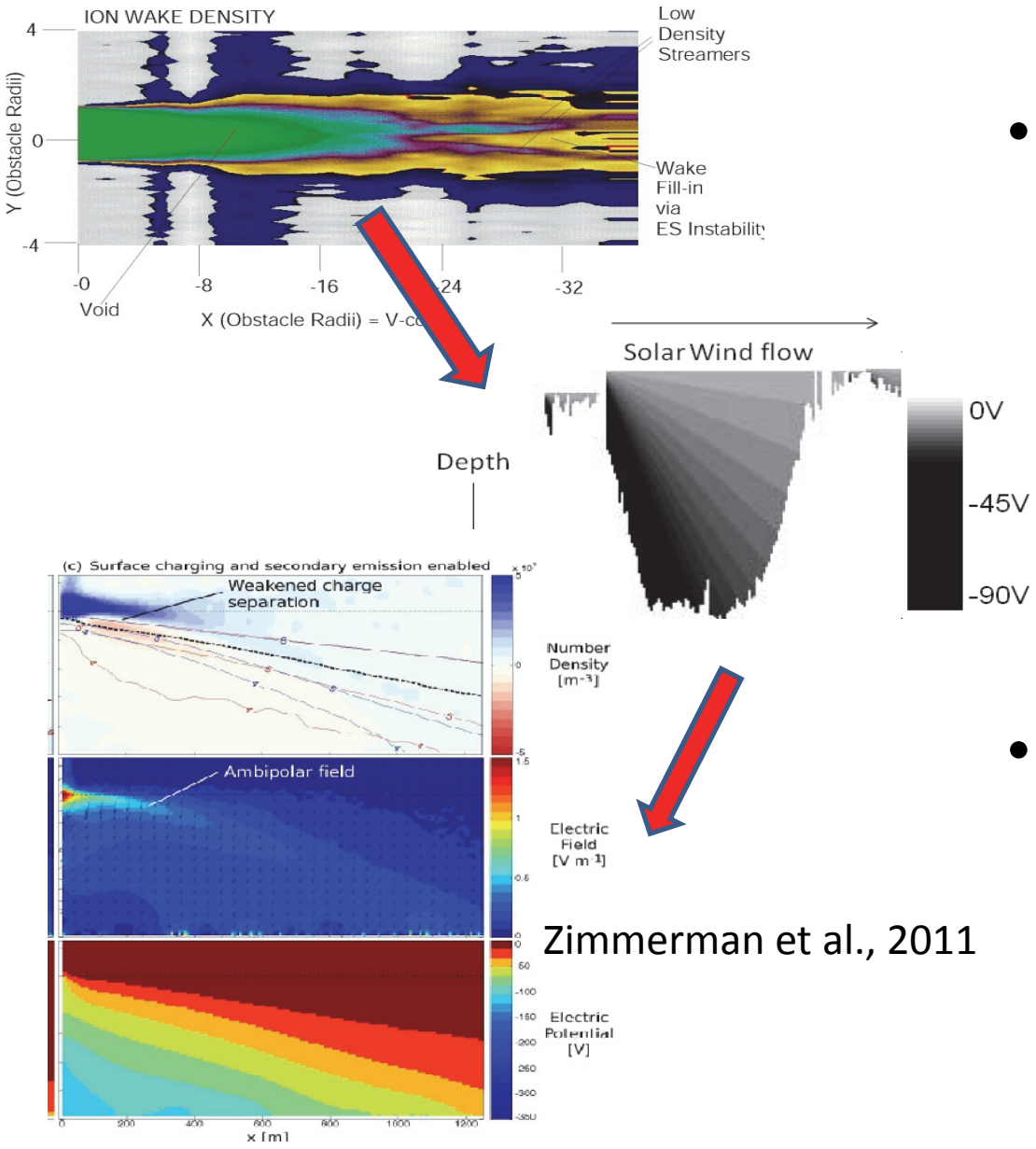
Farrell (GSFC)
Delory (UCB)
Jackson (GSFC)

Stubbs (UMBC)
Marshall (SETI)
Glenar (NMSU)

Krauss-Varben (UCB)
Hesse (GSFC)
Halekas (UCB)
Keller (GSFC)

ARTEMIS Planetary Science Goals and Means	**DREAM Goals**
A. Sources and transport of exospheric and sputtered species, in relation to surface features, as revealed in the charged particle environment	Goal 1. Advance understanding of the surface release and loss of the **neutral gas exosphere** over small to large spatial scales and a broad range of driver intensities.
B. Dust charging and circulation by electric fields.	Goal 2. Advance understanding of the enveloping **plasma interaction region** over small to large spatial scales and over a broad range of driver intensities.
C. Structure and composition of lunar interior as revealed by electromagnetic sounding from orbit.	
D. Surface properties and planetary evolution as revealed by crustal magnetism and space weathering.	Goal 3 Identify **common links** between the neutral and plasma systems and test these linkages by modeling **extreme environmental events.**

DREAM Wake Model Studies



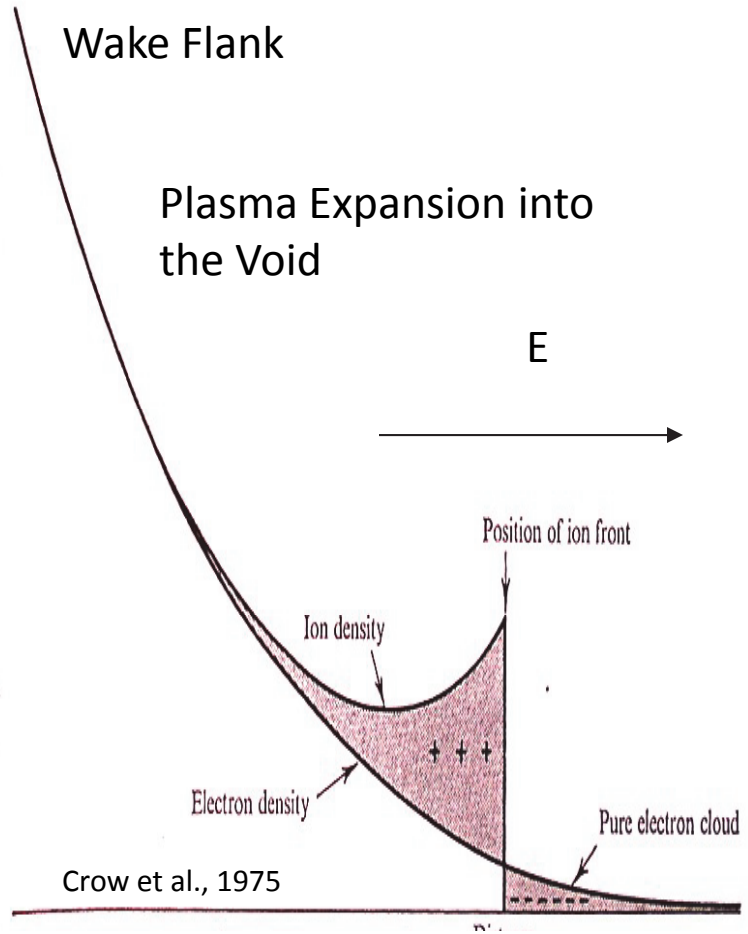
Zimmerman et al., 2011

- Great example of cross-connection

  DREAM very interested in trailing ion sonic wake, from large scale to near-surface wake features

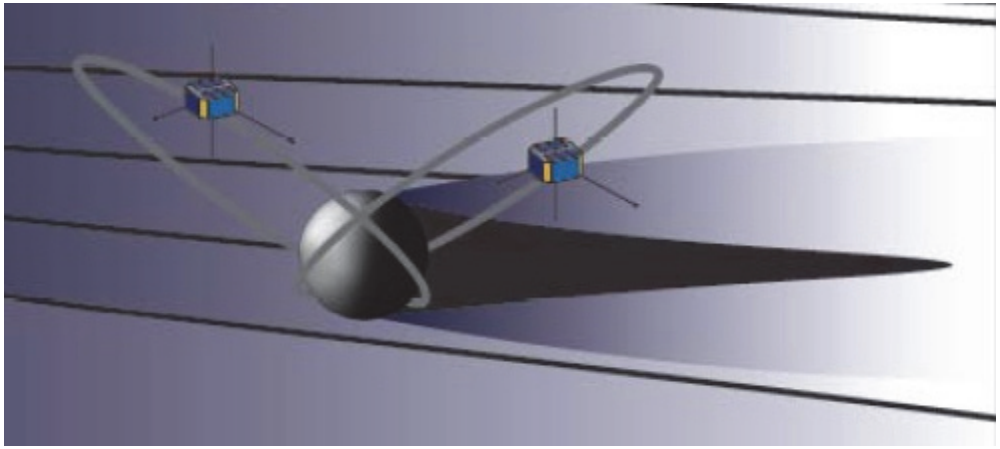
- Try to validate models with LP and new ARTEMIS set

Relaxing Plasma Expansion Quasi-neutrality



- Samir et al [1983] assumed $n_e = n_i$ throughout expansion
- Assumes ions nearly instantly catch up to electrons- convoluted argument
- But do they?
- Crow et al [1975] relaxes this constraint – finds electrons move in ahead of ions

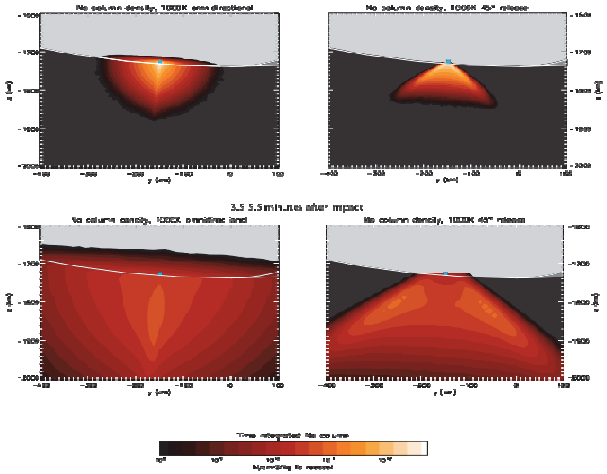
Possible ARTEMIS Targets



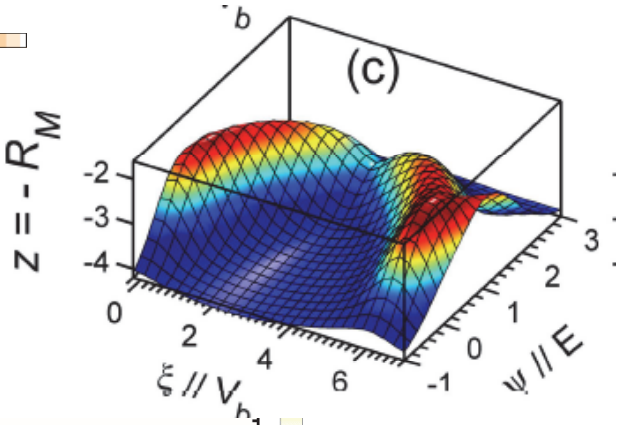
if we can understand the wake structure
at the large scale,
we can infer its structure on the small scale
in craters, etc.

- Proof of the formation of the electron cloud/ion depletion region
- Ambipolar E-field detection
- Wake replenishment (ion-ion vs electron beam instabilities)
- Inflow when B parallel to wake
- Solar storm affects

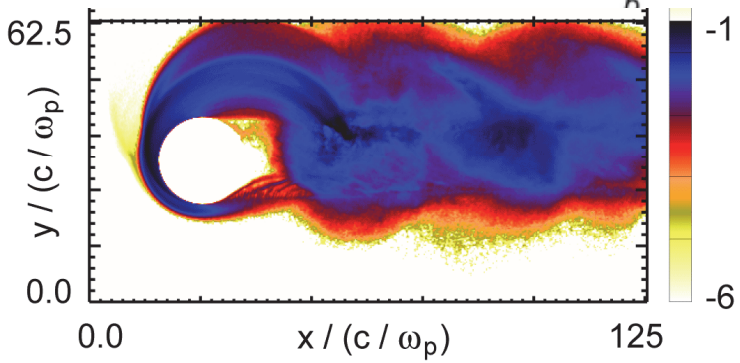
DREAM Exospheric Studies



LCROSS Support
Killen and Hurley



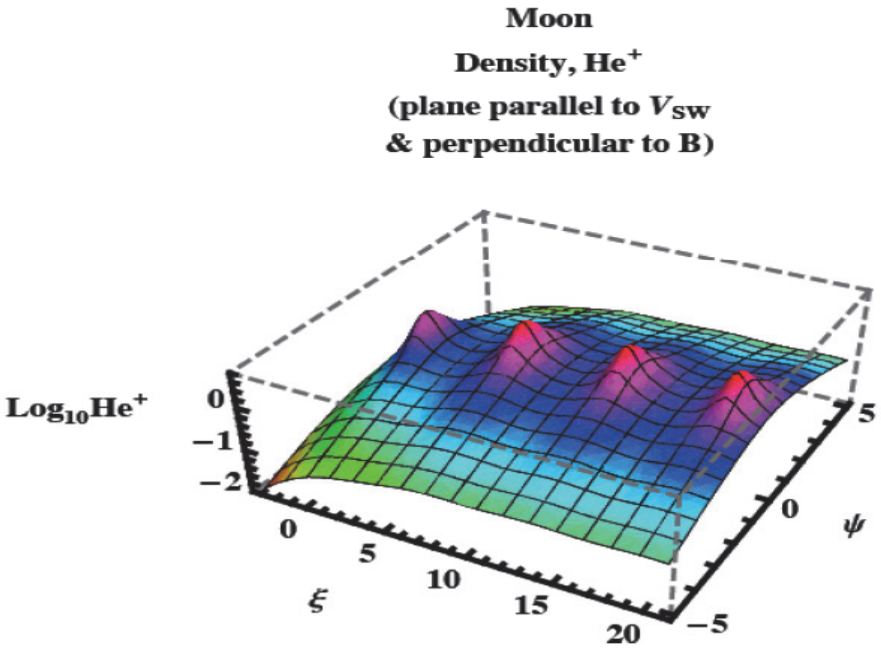
Exo-ion propagation
Hartle and Sarantos



Hybrid sims
of ion environment
Krauss Varben and Travnicek

- Great example of cross-connection
- DREAM very interested in neutral & exo-ion creation and their propagation in the near-Moon environment
- Try to validate models with LCROSS, Kaguya and new ARTEMIS set

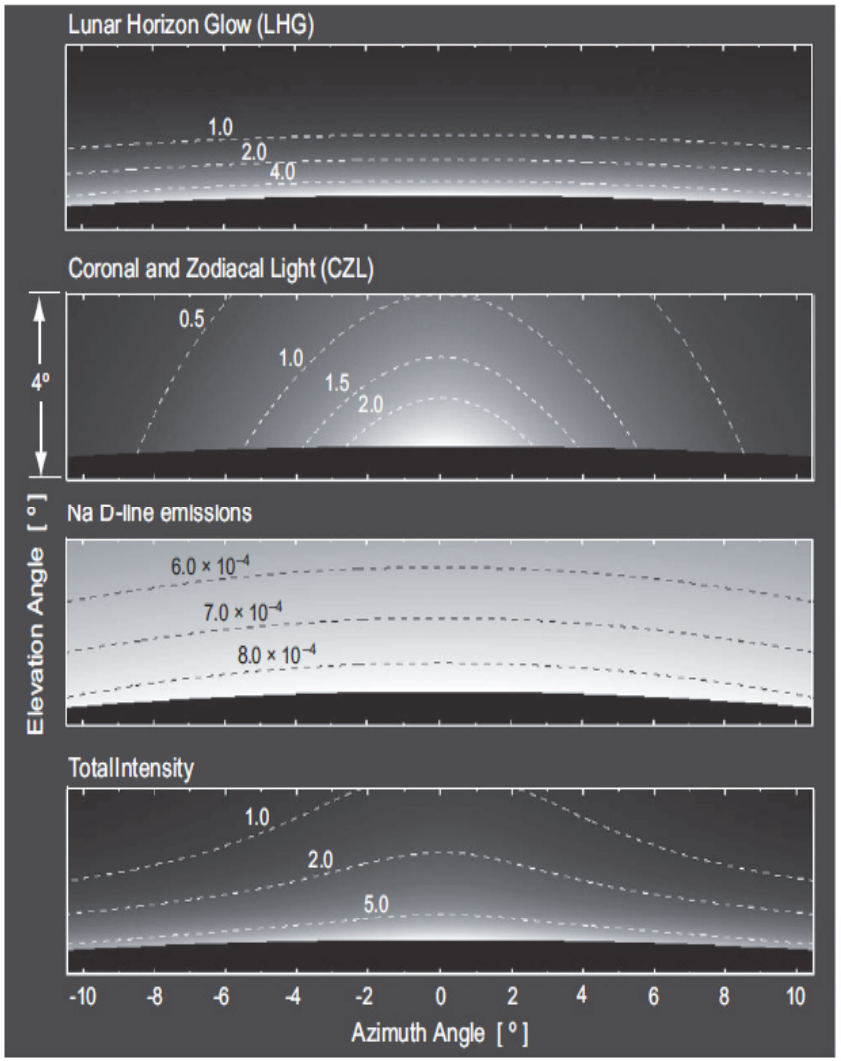
Possible ARTEMIS Targets



Hartle at al, 2009, Fall AGU poster

- Cycloid motion of ions from quasi-localized source
- Get spatial enhancements that very as a function of ion mass
- ARTEMIS can use the Moon as a ‘poor man’s’ mass analyzer

Other Common Topics



- Dust exosphere detection during close passages
- Mag anomalies
- Solar Storms/CME passages by the Moon
- Precursor activity (see Jasper Halekas talk)
- Lunar surface charging (see Andrew Poppe talk)
- Moon as a platform to study deep m-tail plasma (see Tim Stubbs talk)

Stubbs et al., 2010

Conclusion

- DREAM Objective 4: Support ongoing missions
- ARTEMIS and DREAM share some objectives
- DREAM folks can provide community support to missions like ARTEMIS including run models, to consult, help out…but not usurp!
- E/PO :**International Observe the Moon Night on Oct 8**
- Want more information on DREAM and NLSI see http://ssed.gsfc.nasa.gov/dream/