

New Insights Into the Depth Distribution of Hydrogen at the Lunar Poles

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*Subsurface Depth Estimates
H Abundance Estimates
Evidence for Stratigraphy and/or Thermal Profile?*



Builds on a Systematic Reanalysis of Neutron Datasets

- Likelihood-based Statistics Framework
RSM, JGR 117 (2012)
- Comprehensive Thermal & Fast Neutron Analysis
RSM, Nerurkar, Lawrence, JGR 117 (2012)
- Enhanced Surficial Hydrogen at Shackleton
RSM, Lawrence, Hurley, Icarus 233 (2014)

- Fast & Epithermal Neutrons Sensitive to Different Depths

- Fast: “Surficial” Enhancements

- Epi: “Sub-Surface” Enhancements

- Joint Fast-Epi Analysis

Dataset Spatial Distributions on Lunar Surface
(Rates, Exposure, Significance)

- Consider ONLY regions w/ Statistically Significant Epithermal Detections

RSM, Nerurkar, Lawrence, JGR 117 (2012)

- Methodology Enables Robust Statistical Analysis

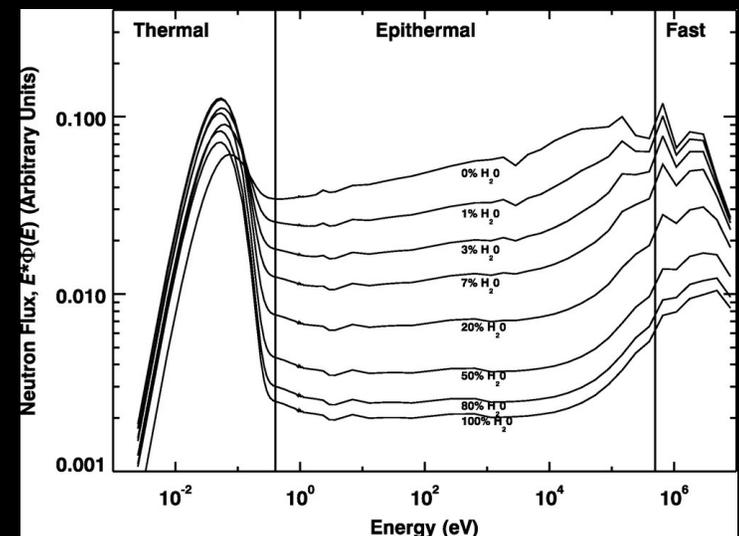
RSM, Nerurkar, Lawrence, JGR 117 (2012)

$\lambda=2\text{LnR}$: Distributed as X^2 Under Null Hypothesis

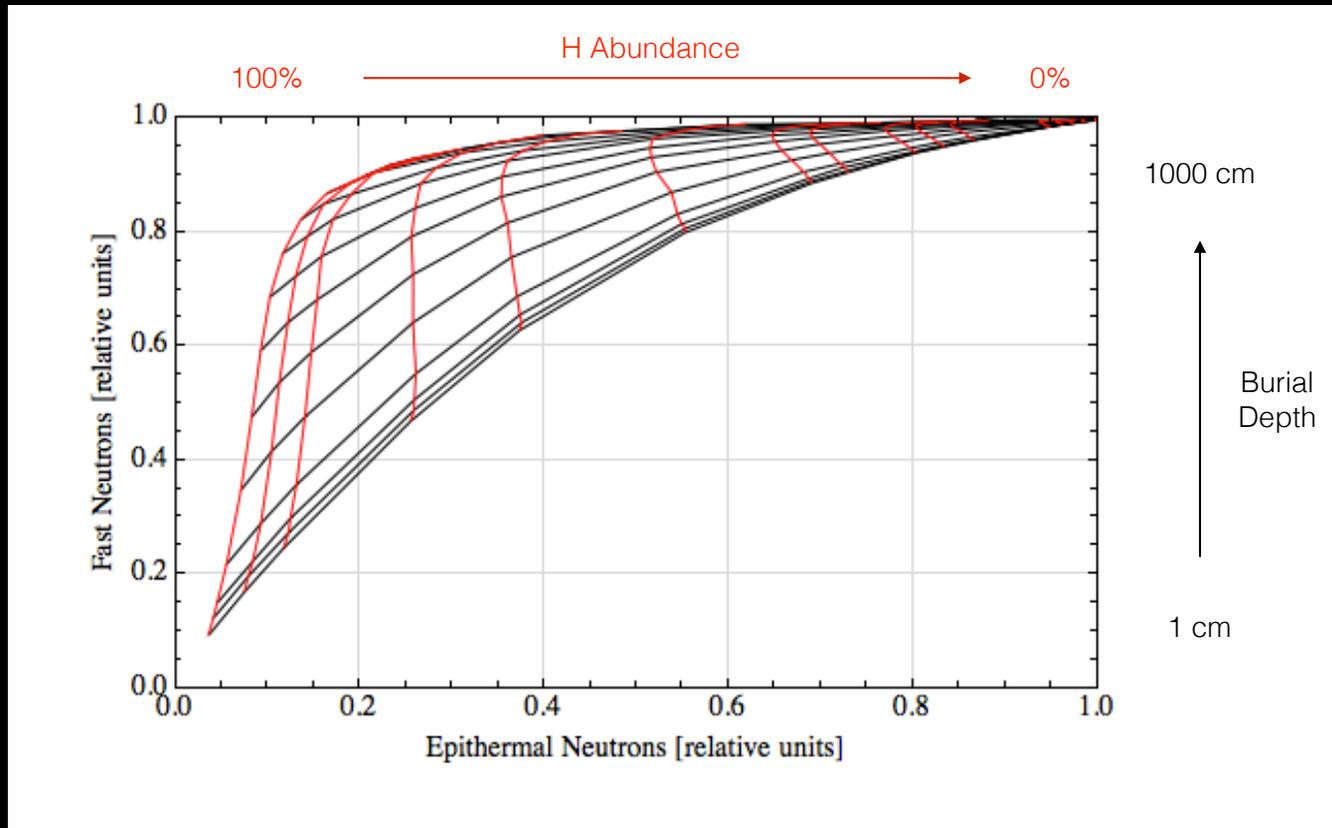
- 90% C.L. Upper Limits

- Detection Thresholds ($\lambda \geq 25$)

- Incorporates Exposures, etc.



Neutron Dataspace



Dataspace Derived Using MCNPX
and FAN-based Regolith

MESSENGER @ Mercury
Lawrence et al. Science 339 (2013)

- Lunar Prospector “Low” Datasets

 - 220.5 days

 - Nominal Orbit Altitude: 30 km

 - ~500,000 individual spectra

 - Fast: LP-GRS → 90% C.L. Limits

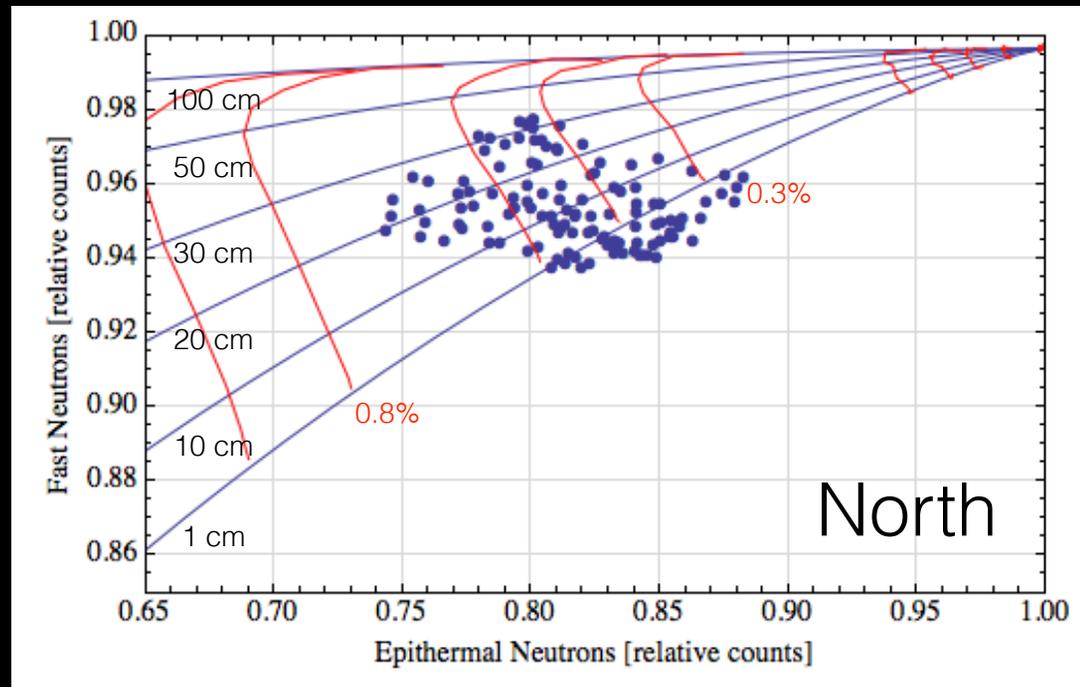
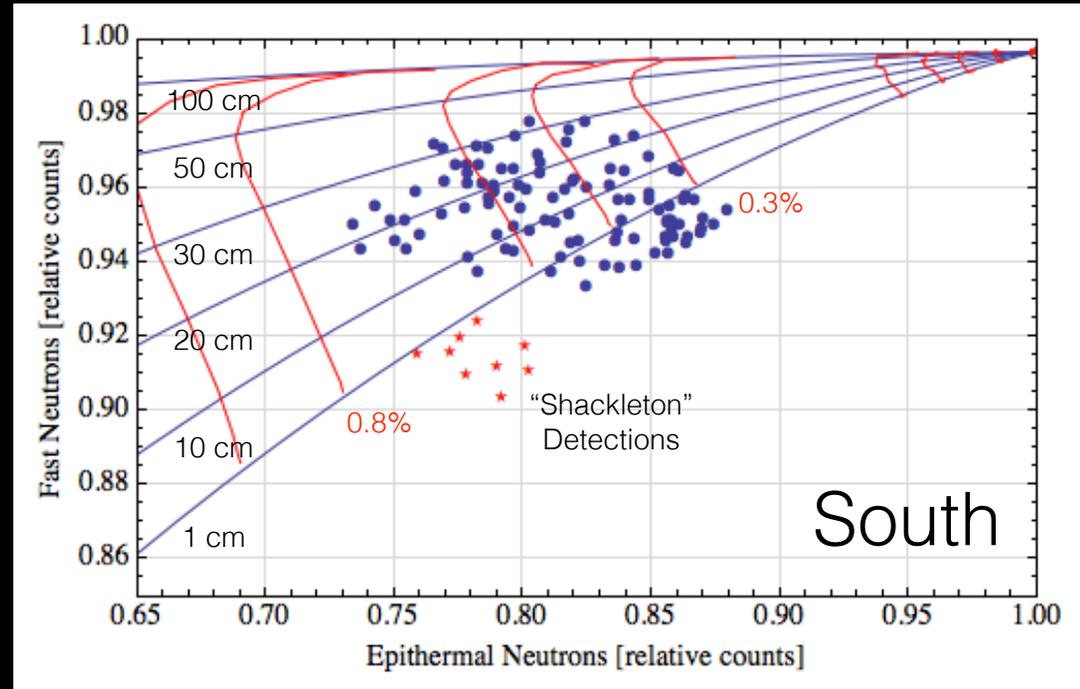
 - Epi: LPNS

- Polar regions: $|\text{lat}| \geq 80^\circ$

- Surface rates via forward-model

 - Lawrence et al. (2006)

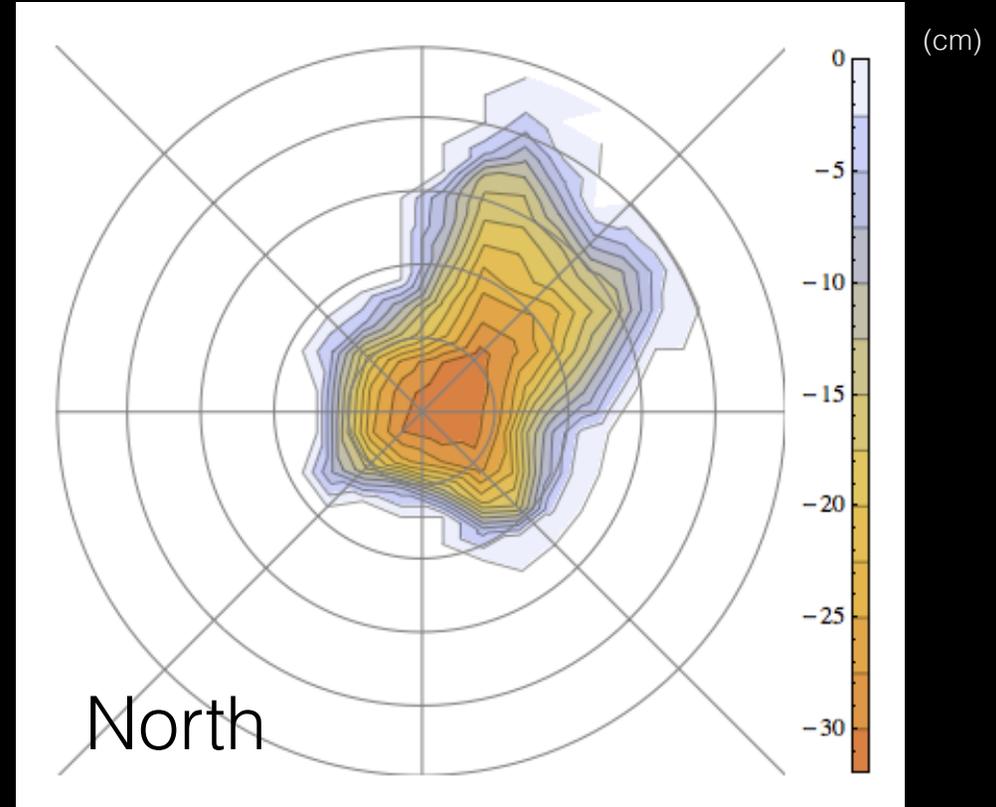
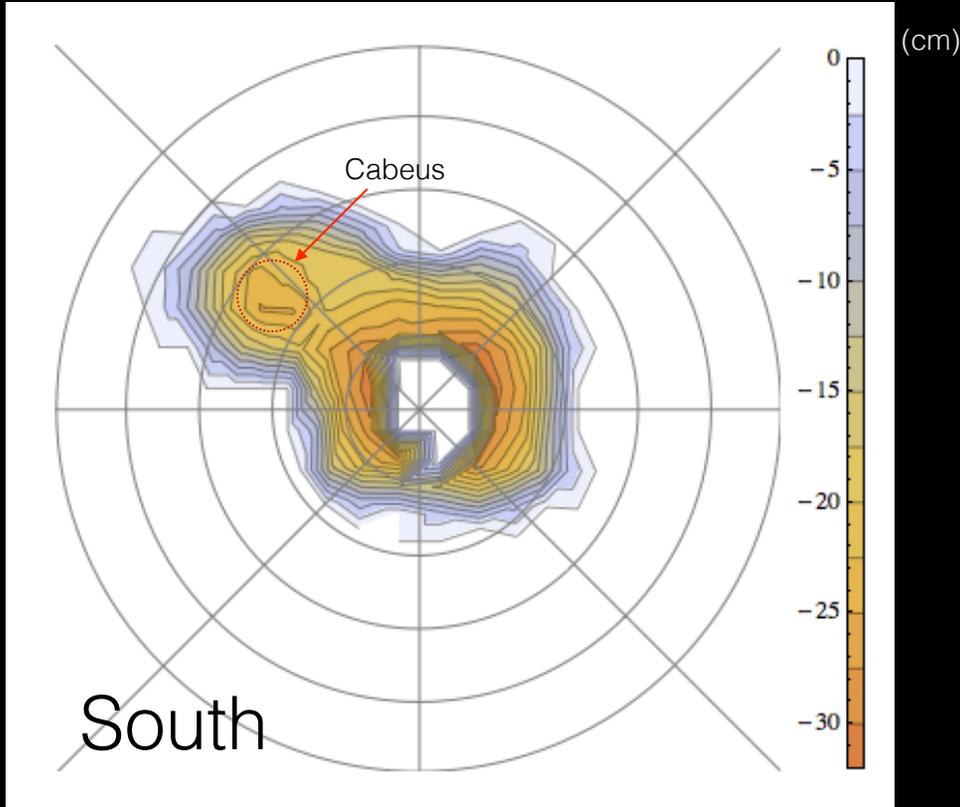
 - RSM, Nerurkar, Lawrence (2012)



Preliminary

Subsurface Burial Depth Estimates

Lower Limit

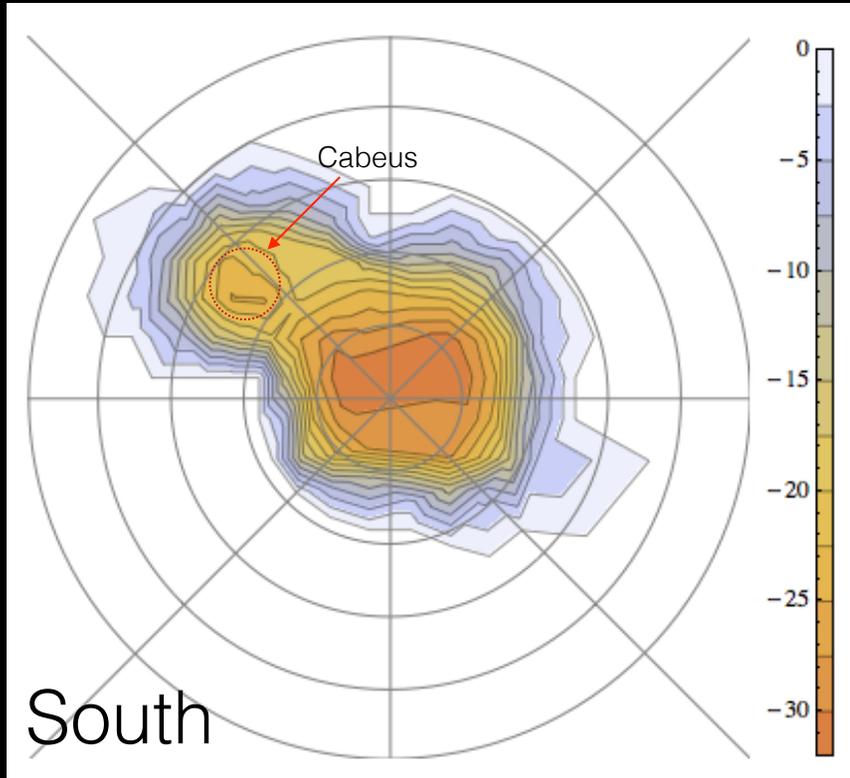


(surficial detections excluded)

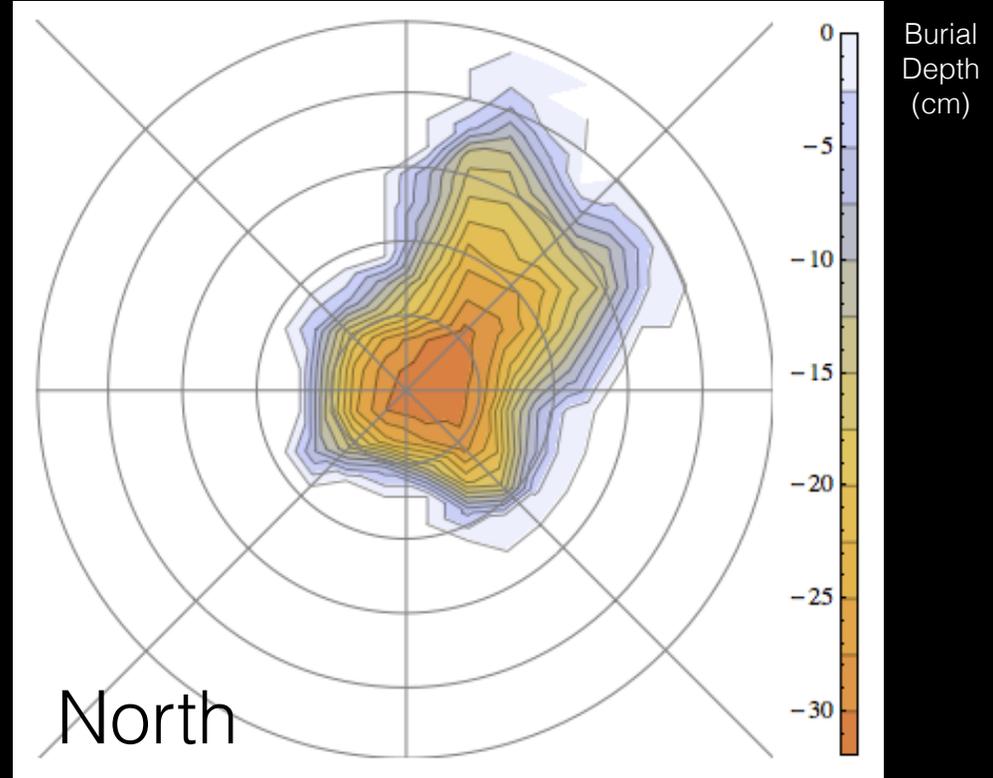
Preliminary

Subsurface Burial Depth Estimates

Lower Limit



Burial Depth (cm)



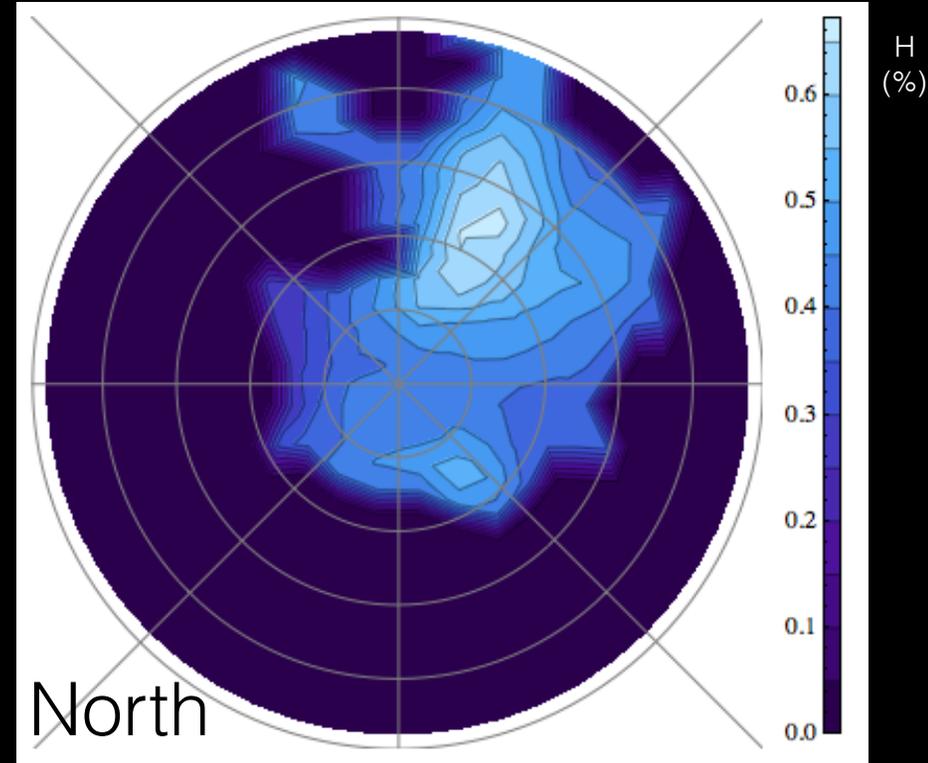
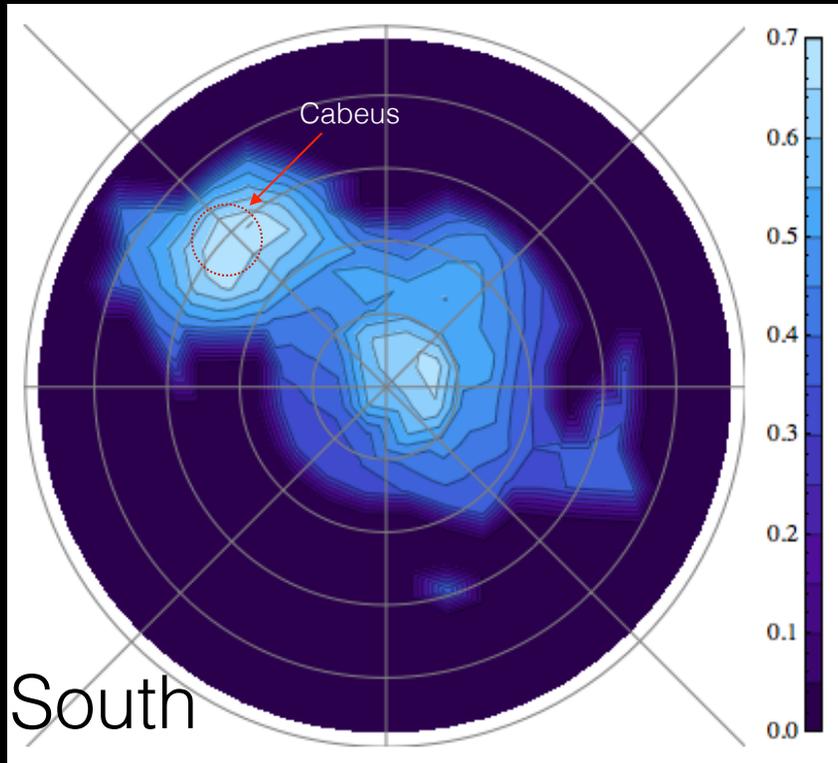
Burial Depth (cm)

(surficial detections ignored)

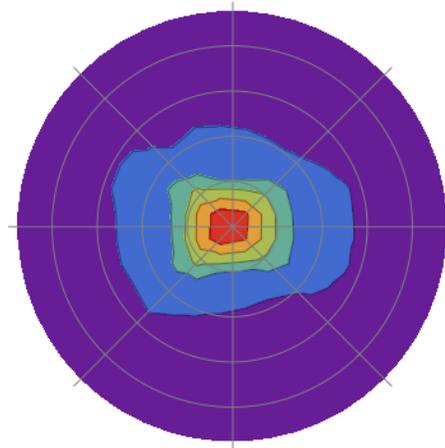
Surface & Subsurface H Abundances

(includes all pixels w/ significant epithermal counts)

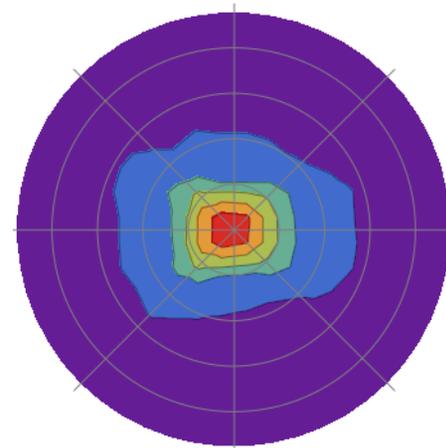
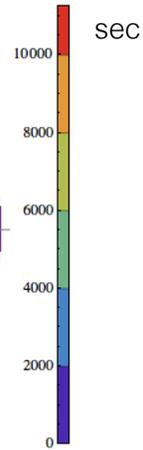
Preliminary



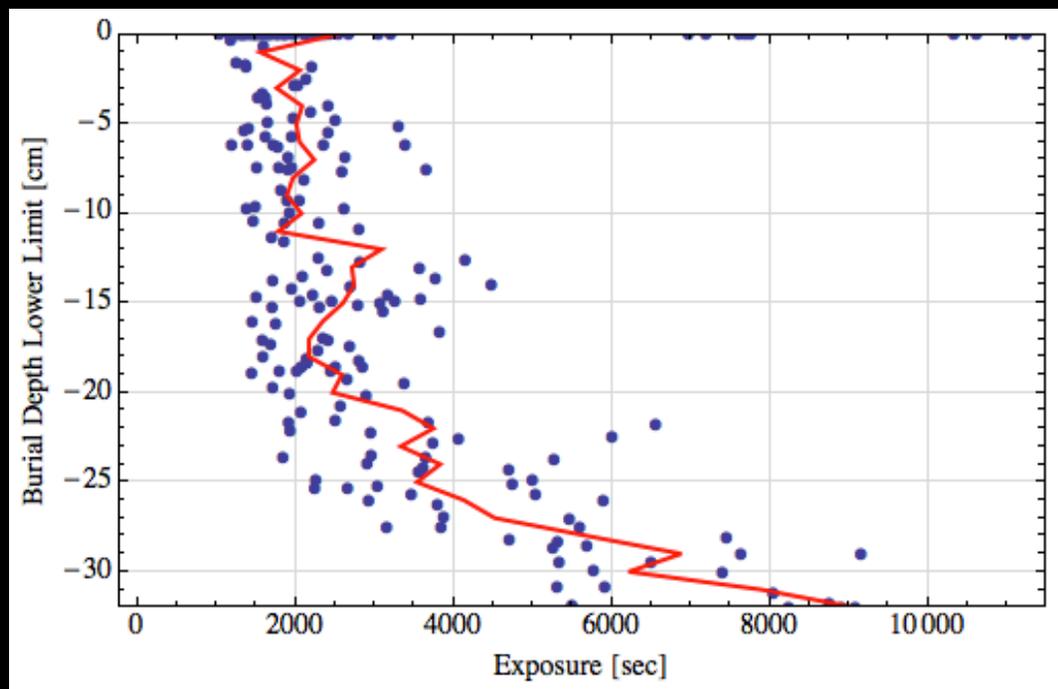
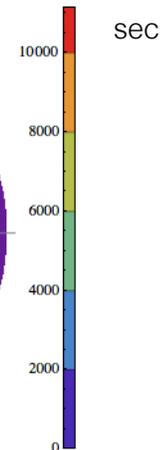
Lunar Prospector Exposure



South



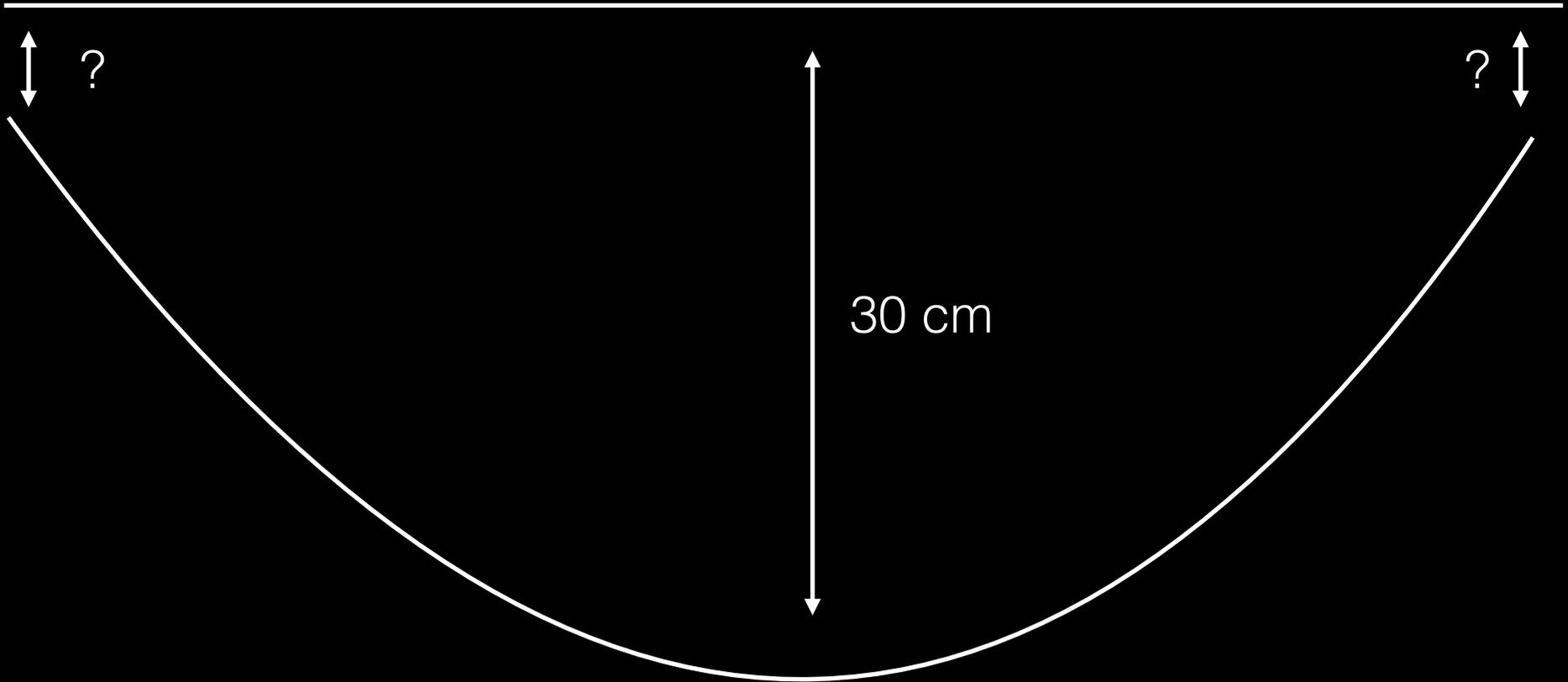
North



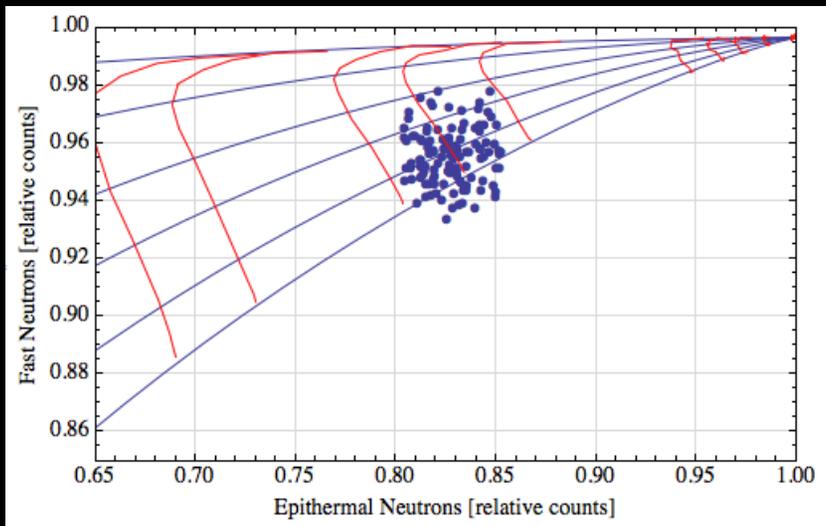
80°

Pole

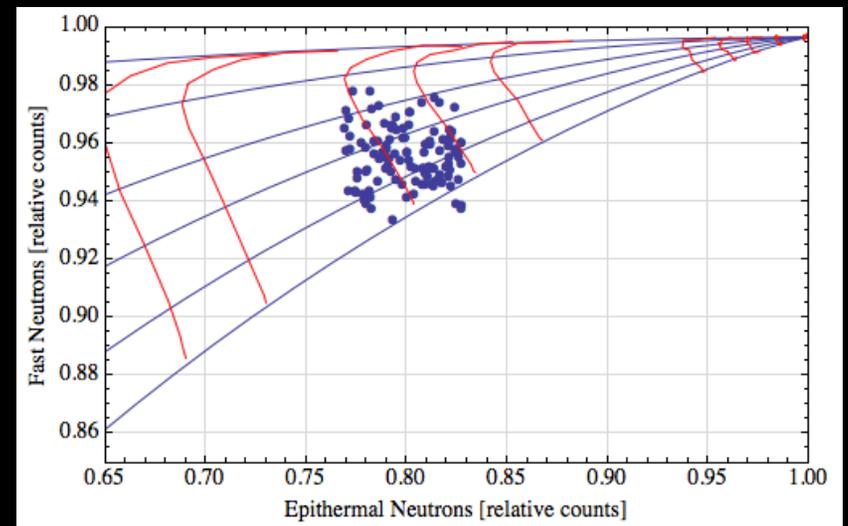
80°



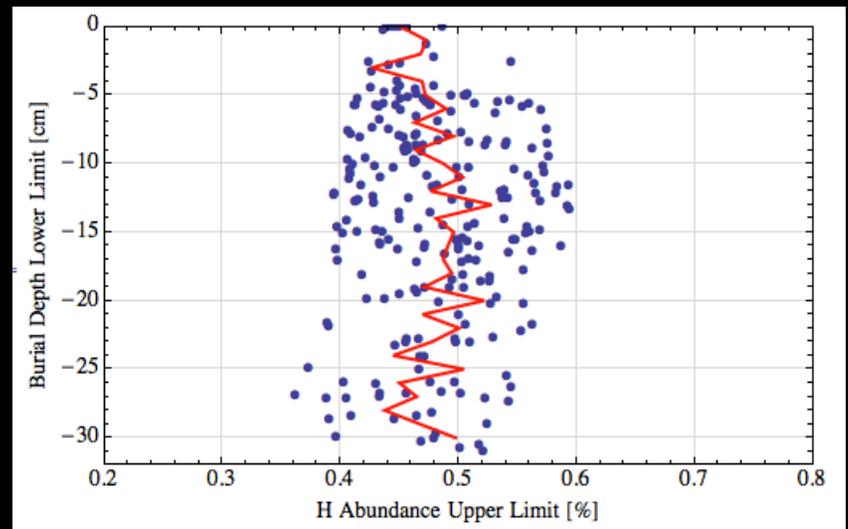
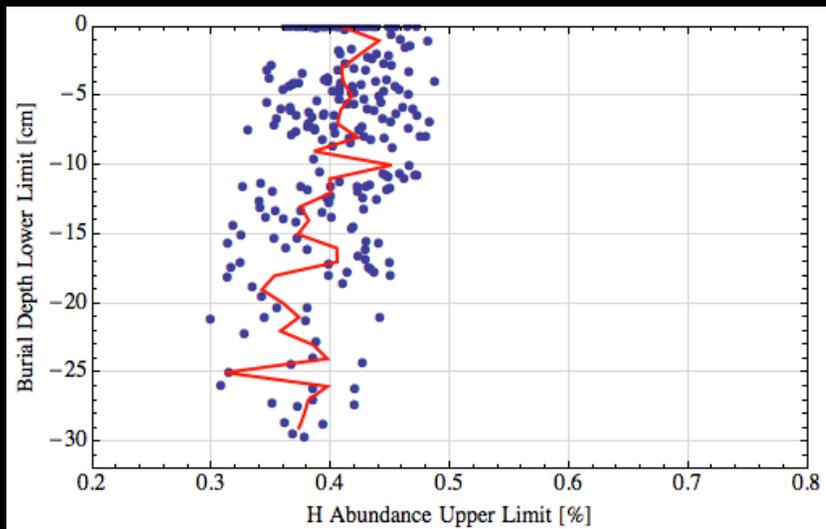
H Abundance: 0.4%



H Abundance: 0.5%



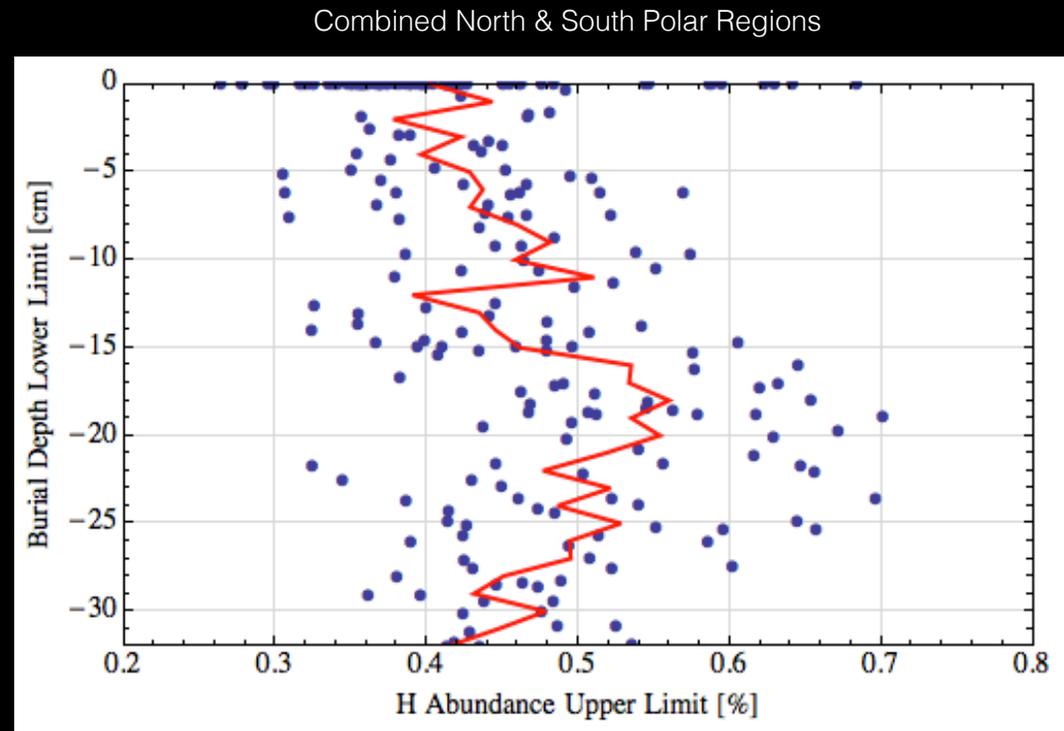
Monte Carlo Examples



Burial Depth Profile

Preliminary

- Use derived depth & H abundances
- Abundance variation w/ depth(?)
Statistics Limited
- Exposure Systematics?
 - Shallow vs. Deep ($>3.5\sigma$)
 - MC-Constant Abundance ($>6\sigma$)
- Evidence of thermal profile?



Summary

- Continued Re-Analysis of Global Neutron Datasets (LP)
 - Joint Dataset Analyses
 - Burial Depth Lower Limits
 - H Abundance Estimates
- Possible Evidence for Polar Depth Non-Uniformity
 - Derived via Statistical Upper Limits on Fast Neutrons (Intrigue & Caution)
 - Significant & Robust
 - Thermally-Induced Diffusion?
- Motivate New Investigations
 - Exposure Enhancements
 - Multi-Messenger (Fast+Epi) Benefits
- Inputs Into Source & Evolution Models