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Distribution of surface water ice on the Moon:

An analysis of host crater ages provides insight into the ages and sources of ice at the lunar south pole.

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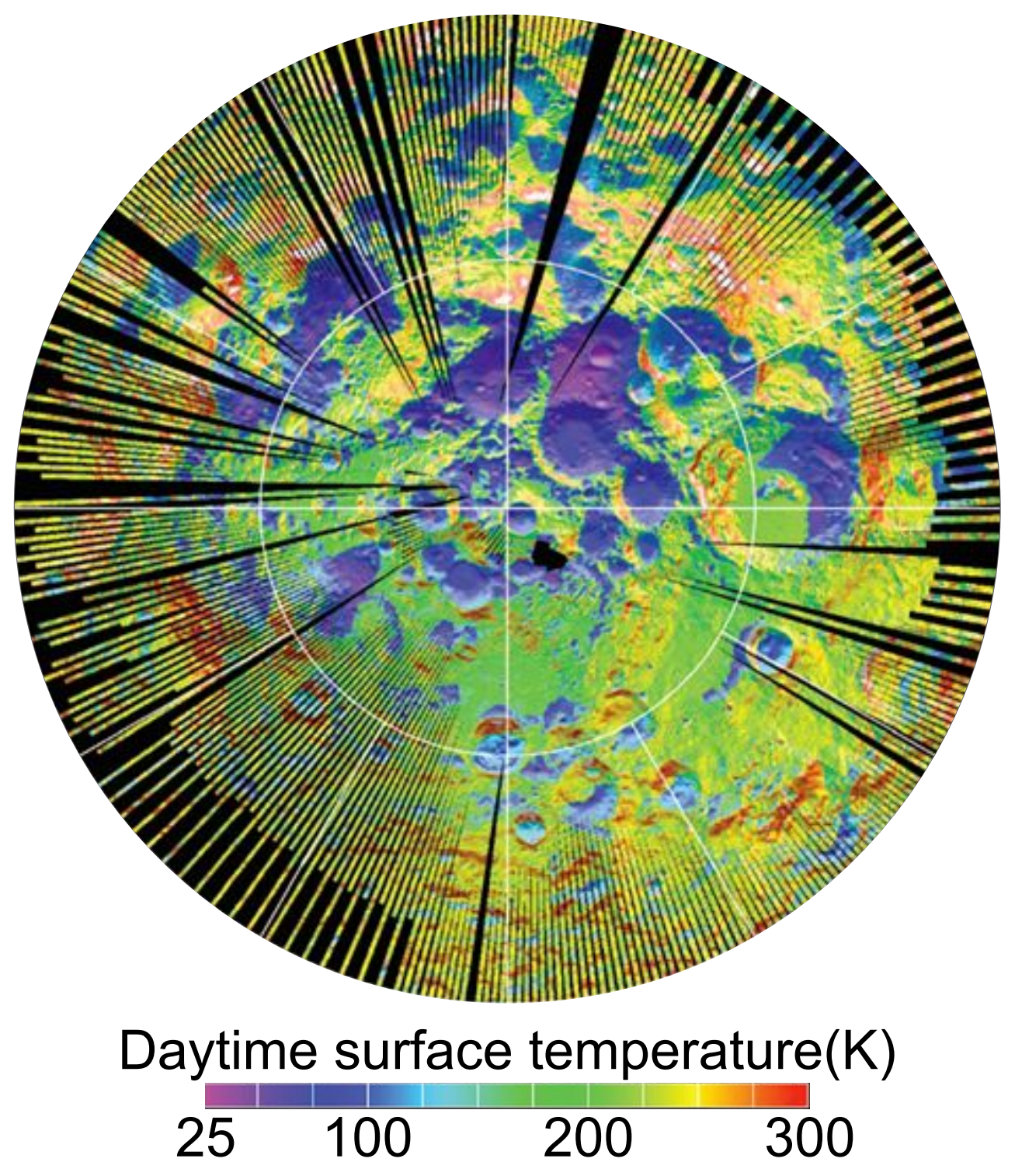
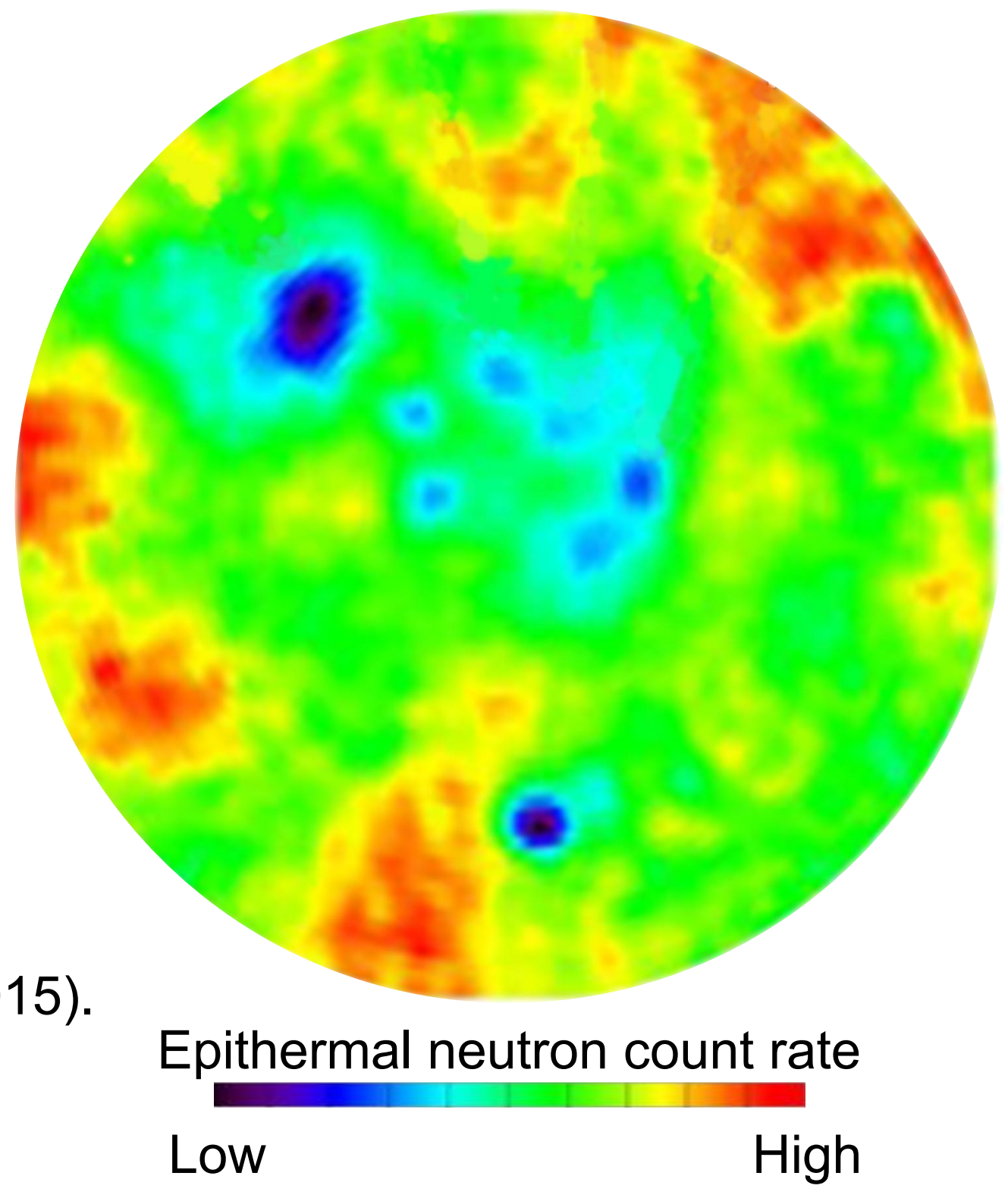
Surface ice on the Moon

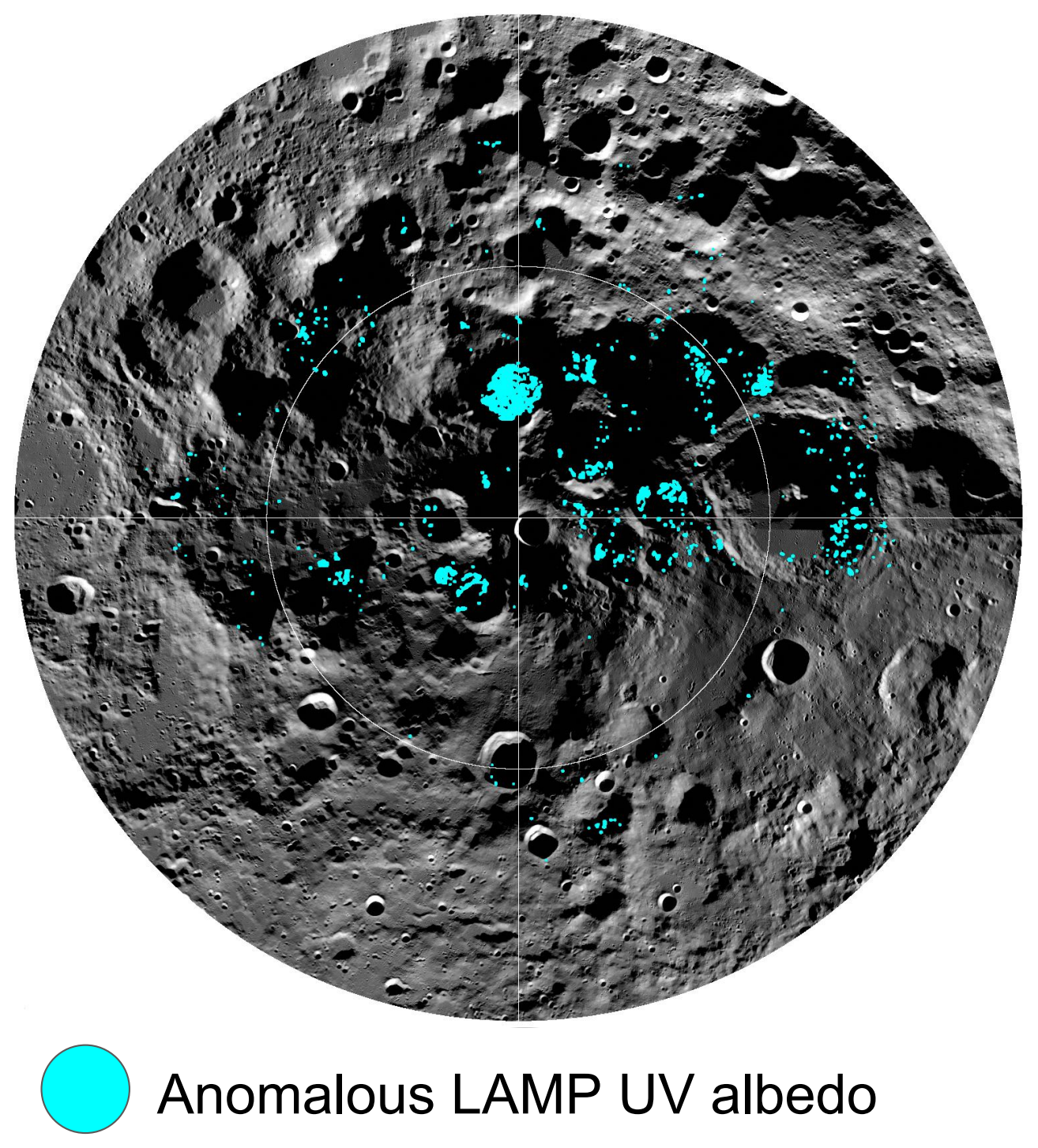
Extremely low surface temperatures (<110 K) are conducive to the cold-trapping of water ice over geologic timescales (Paige et al., 2010).



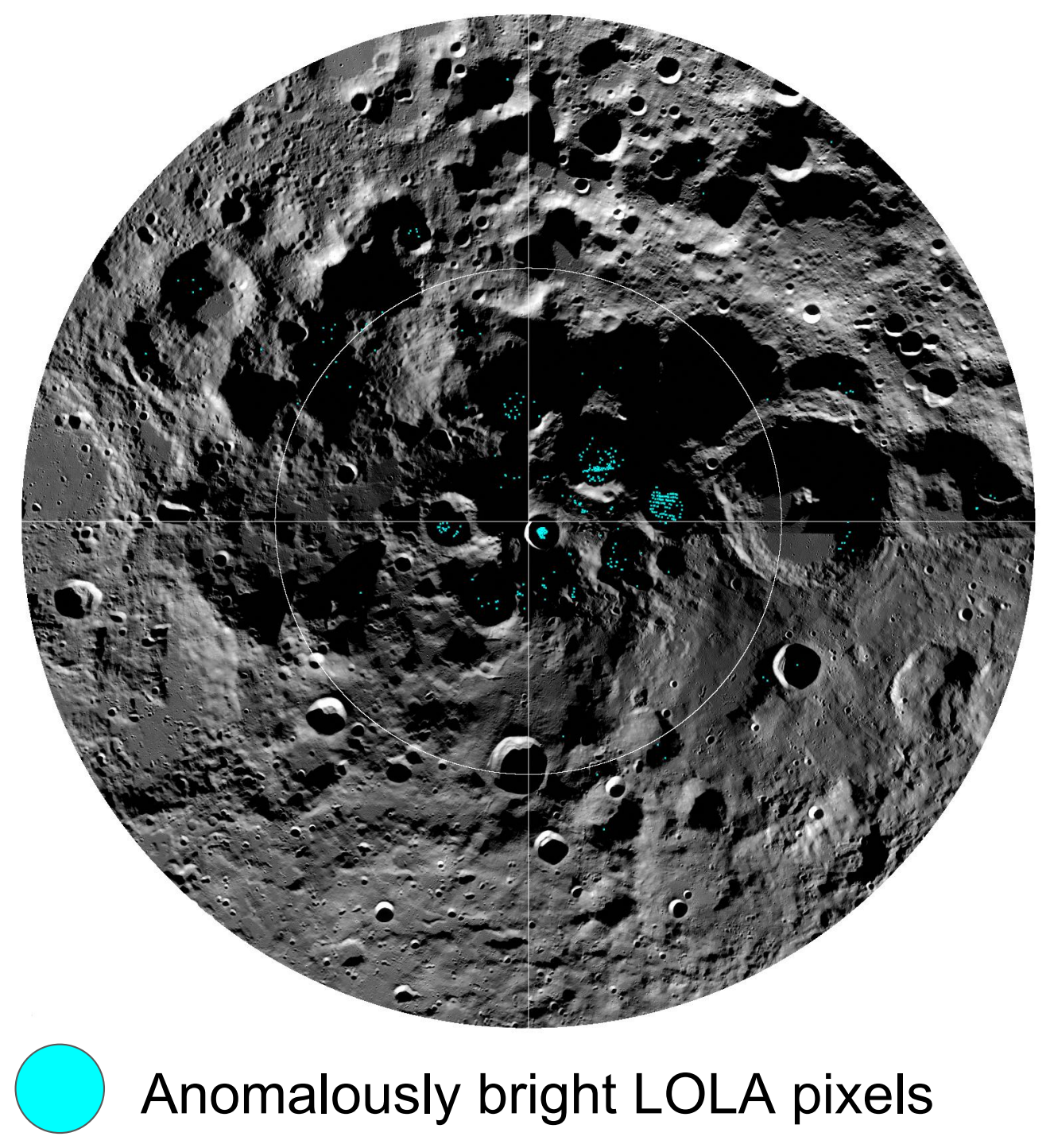
Analysis of thermal and epithermal neutron counting rates suggest that the average hydrogen abundance at both poles is 100–150 ppm (Lawrence et al., 2006; 2015).



Mapping of UV albedo spectra and surface temperature measurements reveal a highly spatially heterogeneous distribution of water frost within PSRs (Hayne et al., 2015).



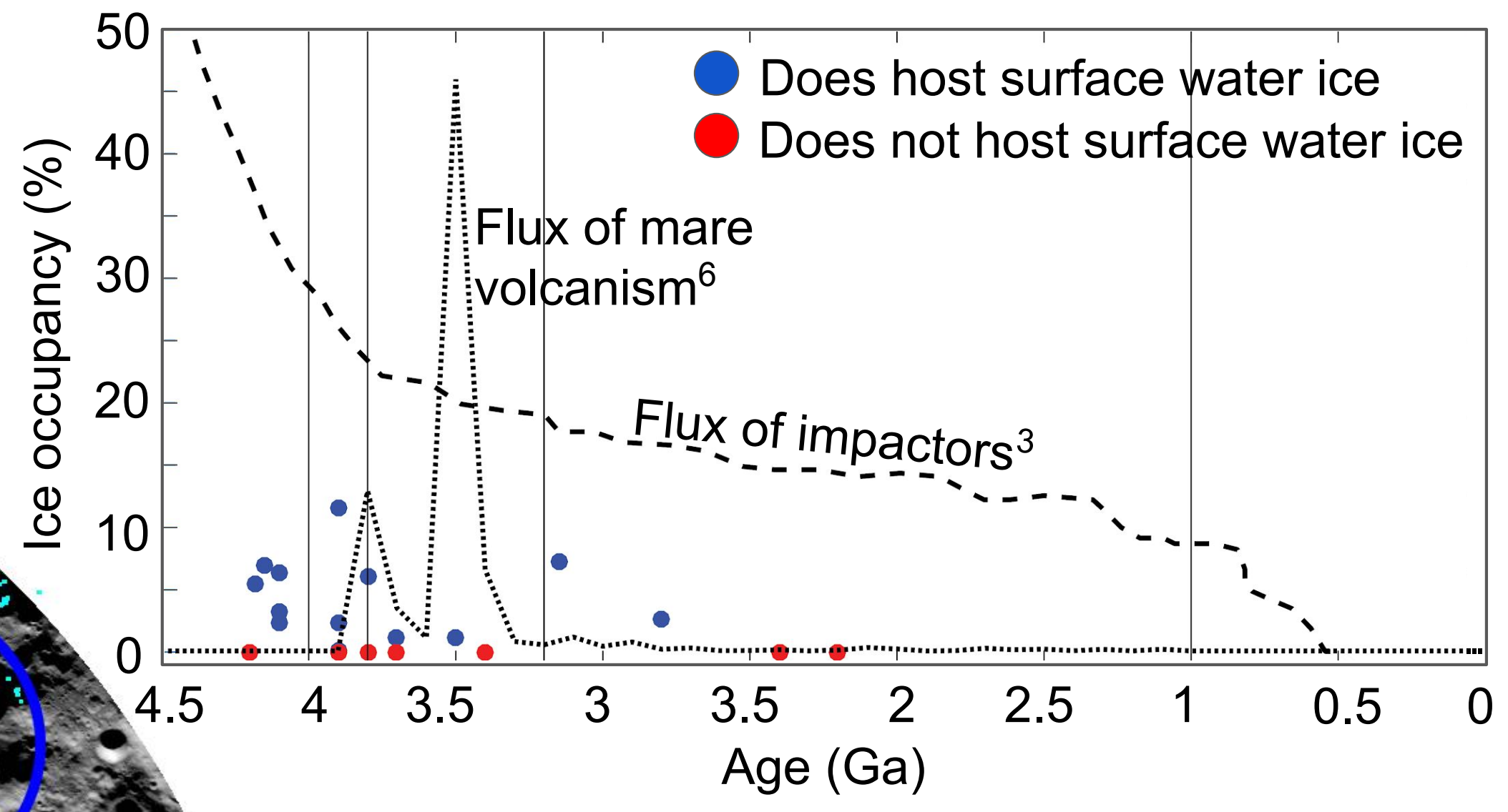
Enhanced surface albedo suggestive of water frost in regions with surface temperatures <110K also indicates a patchy distribution of surface water ice (Fisher et al., 2017).



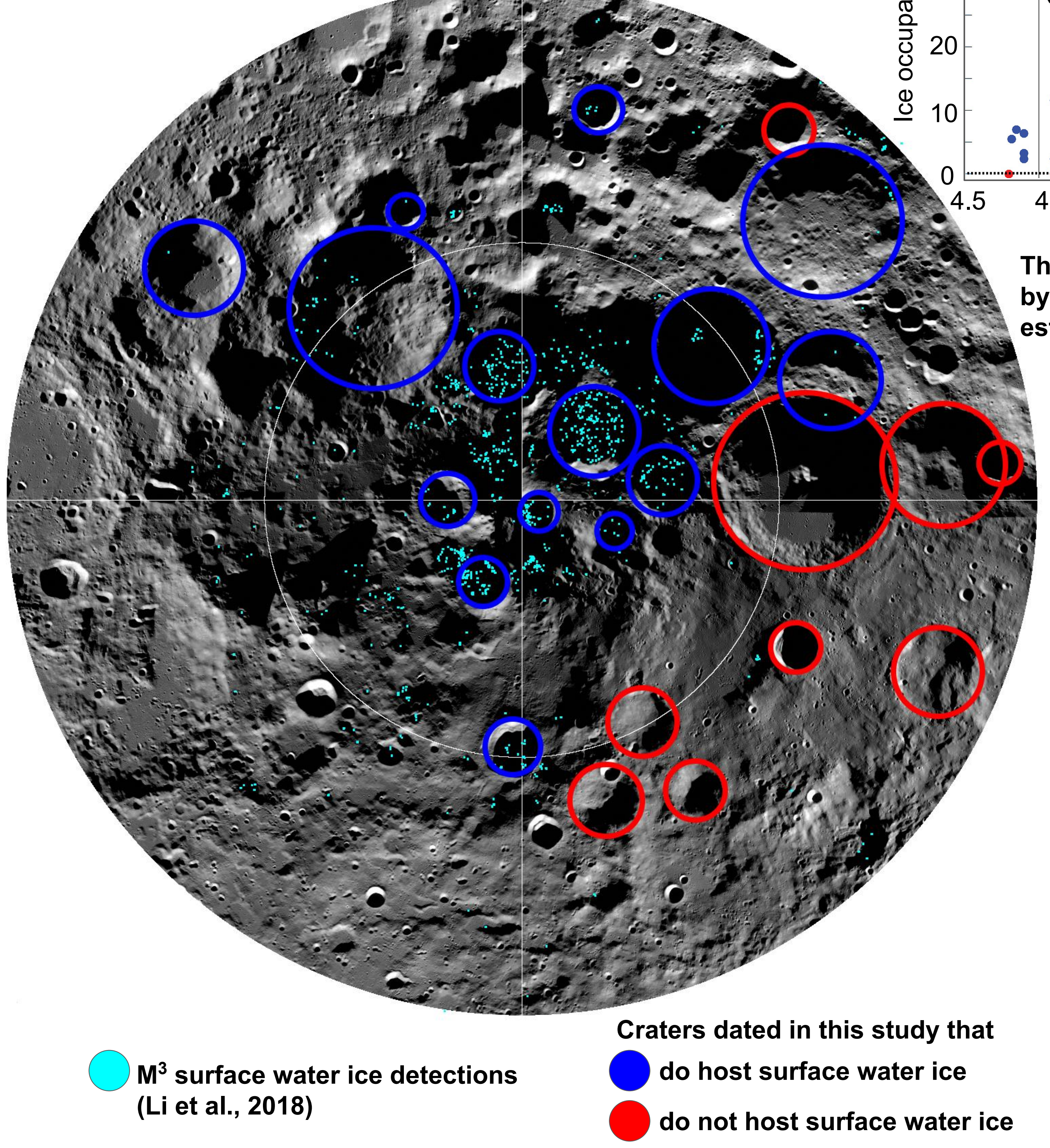
Motivating questions

1. What are the ages of lunar craters that host surface ice?
2. What do the ages of host craters suggest about the timing and source(s) of ice delivery?

Results



The percentage of specific cold traps occupied by water ice is plotted with respect to the estimated model ages of the host craters.



- The majority of surface water ice at the lunar south pole [1] is found in large, old (>2.8 Gyr) craters, which comprise the majority of the cold-trapping area available (*left*).

- There are also some ancient craters that are present-day cold traps, but do not host surface water ice (*left*). Under predicted paleoconditions [2], the thermal surface environments of these craters would not have been stable for the survival of surface water ice.

Possible sources of water ice

- Ancient ice may have been delivered by impactors [e.g., 3]. Early impactors were likely to be delivering ice to the lunar poles, in addition to breaking up and covering the ice [4,5], consistent with the patchy surface distribution observed today.

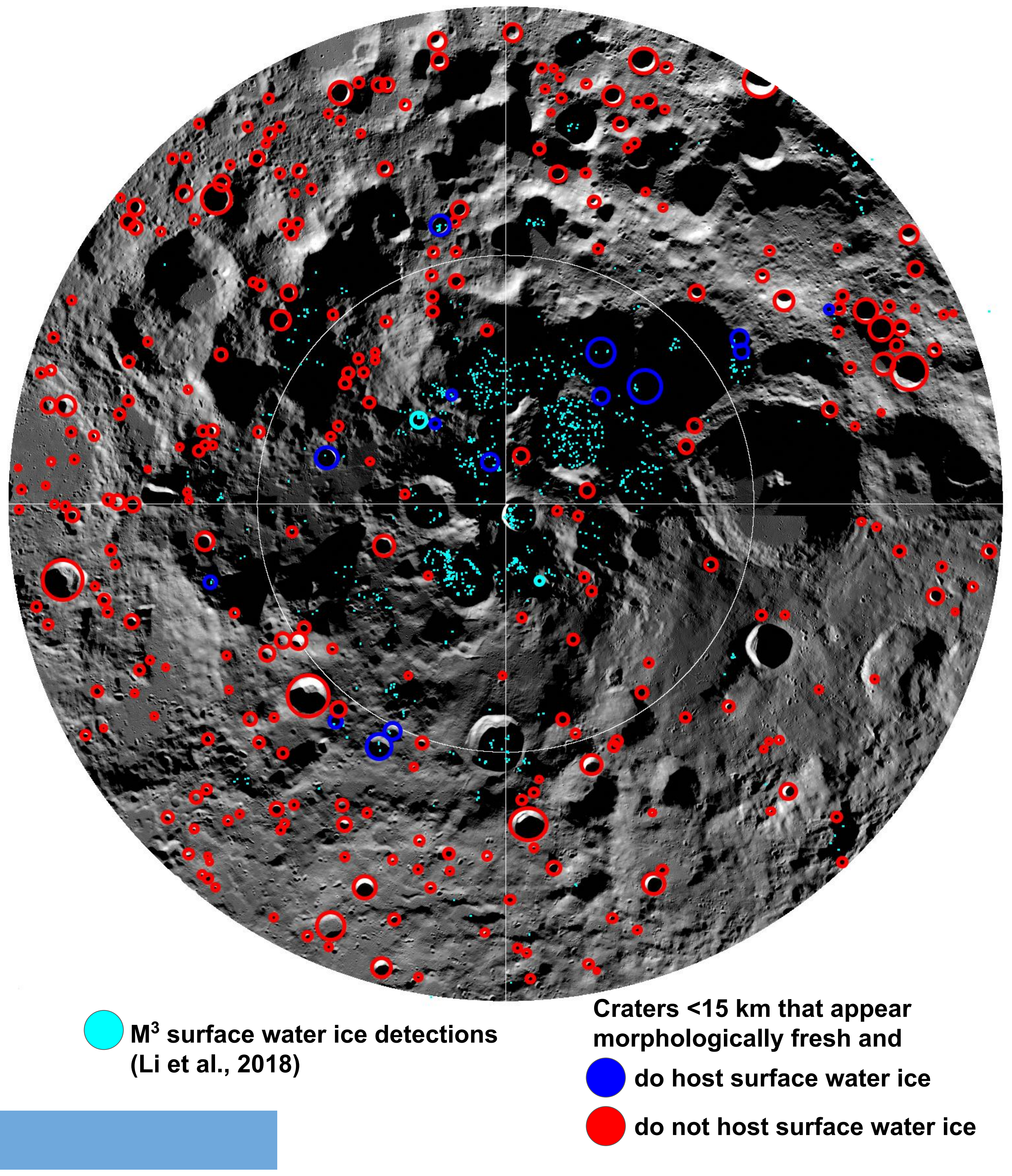
- Ancient ice may have also been volcanically outgassed [e.g., 6]. But if TPW already had occurred before peak mare emplacement ~3.5 Ga [2], then the ancient craters that lack surface ice today would have been available to trap surface ice. The lack of ice in specific ancient craters (*above*) suggests that volcanism did not deliver ice, or delivered ice that has since been destroyed. the inventory of surface ice observed today is not primarily sourced from mare volcanism.

- The population of small (<15 km), fresh-looking impact craters suggests that some ice has been delivered to the surface more recently. The surface water ice may source from micrometeorite delivery as well as from solar wind interactions with the lunar regolith [e.g., 7].

- No more than ~11.5% of the surface areas of polar craters are occupied by water ice (*left*). The very patchy surface distribution of ice suggests that the rates of destructive processes exceed the rates of ice emplacement.

- We identify 301 small (<15 km in diameter) impact craters that are likely to be relatively young, given sharp crater rim morphologies (*right*).

- ~5% of these craters (*right*), which are too small for crater counting analyses, have at least one pixel with a positive ice detection [1].



Conclusions

- **The majority of surface ice is contained in old craters >2.8 Gyr, where the majority of cold-trapping area on the pole exists, and is very patchy in surface distribution, occupying <11.5 % of cold-trapping surface area available in individual craters.**
- **Ice within fresh, relatively young craters suggests that ice has more recently been delivered to the lunar surface, perhaps from micrometeorites or through solar wind interactions with the lunar regolith.**
- **The low percentages of cold trap surface areas that host surface water ice on the Moon are in stark contrast to the host craters on Mercury that are occupied by laterally contiguous ice deposits [8–10] and may reflect a difference in age of the ice [11].**
- **Understanding when the ice was delivered to the lunar surface as well as the physical delivery mechanism(s) are of critical important to unraveling the nature of these ice deposits, which has implications for the source and evolution of volatiles on other airless bodies and across the inner Solar System.**

References

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