The first ever energetic neutral particle measurements on the lunar surface:

A Swedish instrument on a Chinese lunar rover

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### Solar wind and the moon: its complicated



<sup>[</sup>Futaana, 2009]



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### Chandrayaan-1, 2009: the glow



[Wieser and Wieser, 2019]

Cool stuff here

(Magnetic

anomaly)



## But: Regolith is very porous, why is anything reflected?



Micrograph images of lunar regolith. Each panel is about  $40\mu m$  wide (from Zbik et al. [2010]).



### A lot of open questions

Why is the **apparent scattering rate** for the solar wind-surface interaction is **so high**?

How does the **near-surface neutral and plasma environment** look like at the 1-m scale?

How does the solar wind interact with **porous lunar regolith** and does it differ from laboratory experiments?

How do the emitted energetic neutral atoms control the **dynamics of the lunar exosphere**?

How does the **regolith evolve due to solar wind sputtering**?



### To the surface! The classical first napkin sketch.





### 10 years later: back on the moon with Chang'E 4





CHANG,

### The Advanced Small Analyzer for Neutrals (ASAN) on the Yutu-2 rover



# First measurements of energetic neutral atoms on the lunar surface





## **Observations**

- More than 2 years of observations and no instrument degradation!
- Data form ~9h and ~15h lunar local time (thermal constraint)
- ASAN measures when the rover is not moving
- Even coverage in solar azimuth
- Different solar wind and interplanetary magnetic field orientations



Observation geometry





### Energetic neutral atom data from the lunar surface



Energetic neutral hydrogen energy spectrum cutoff follows solar wind energy

Confirms Chandrayaan-1 measurements

About 10% to 20% of solar wind protons are reflected as energetic neutral atoms



### Keeping warm, but we get our own radiation background







Backscattered and

#### Sputtered from **lunar** surface

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[Wieser et al., 2021, in preparation]



### How about even heavier energetic neutral atoms?





### We update our onboard tables



Focus on lower energies only (max energy: 1keV)

Extend mass coverage (~ 2x higher maximum mass)

There are a few iron atoms !(?) More calibration is needed...





### Summary

50 years after Hasselblad, Swedish instrumentation is back on the lunar surface onboard of the Yutu-2 rover.

The ASAN instrument performed the first ever energetic neutral atom measurements on the lunar surface.

The instrument is in very good health and has been running on the surface for more than two years and counting.

A semi-analytical model of the sputtering process of lunar regolith by solar wind is being developed to better understand the long term evolution of the lunar surface and exosphere.

